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HARMSWORTH'S WIRELESS ENCYCLOPEDIA

For Amateur & Experimenter

UNI—ZIR

CONSULTATIVE EDITOR

SIR OLIVER LODGE, F.R.S.

Among the Contents of this Part are

VALVES FOR RECEPTION

by Dr. E. V. Appleton

VALVES FOR TRANSMISSION

by Dr. W. H. Eccles

WIRELESS WAVES

by Sir Oliver Lodge

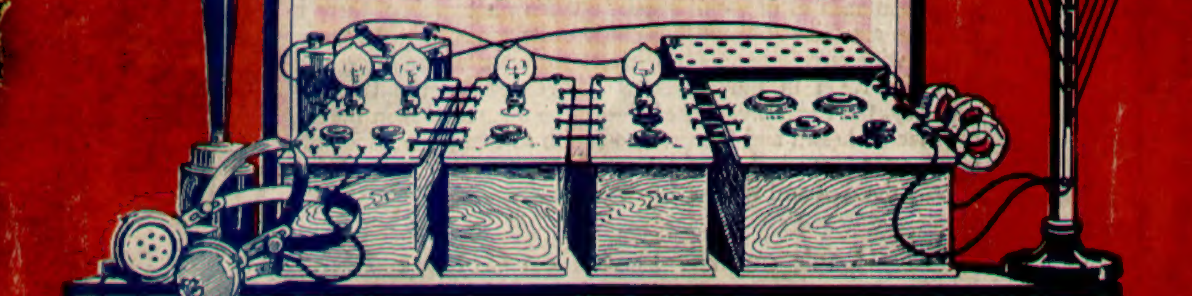
Special Photogravure Plate :

RECEIVING SET WITH MYERS VALVES

COMPLETE CLASSIFIED INDEX

Back Numbers to Complete Your Set Can Still be Obtained!

J. LAURENCE PRITCHARD, F.R.Ae.S., Technical Editor, with expert editorial and contributing staff



See Important Announcement "To Our Readers" Overleaf

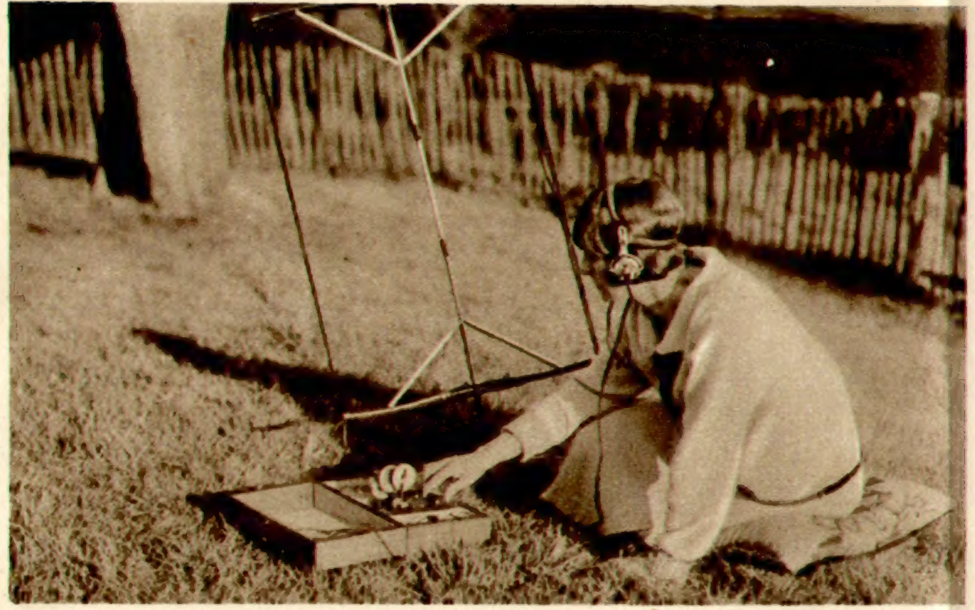


Fig. 9. The neatness and compactness of this set, and the robustness of the Myers valves, make it particularly suitable for out-of-doors use

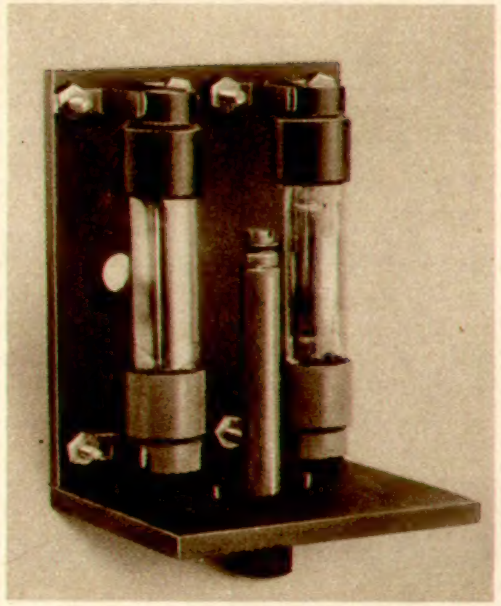


Fig. 10. How the Myers valves are mounted. The grid leak is shown between them

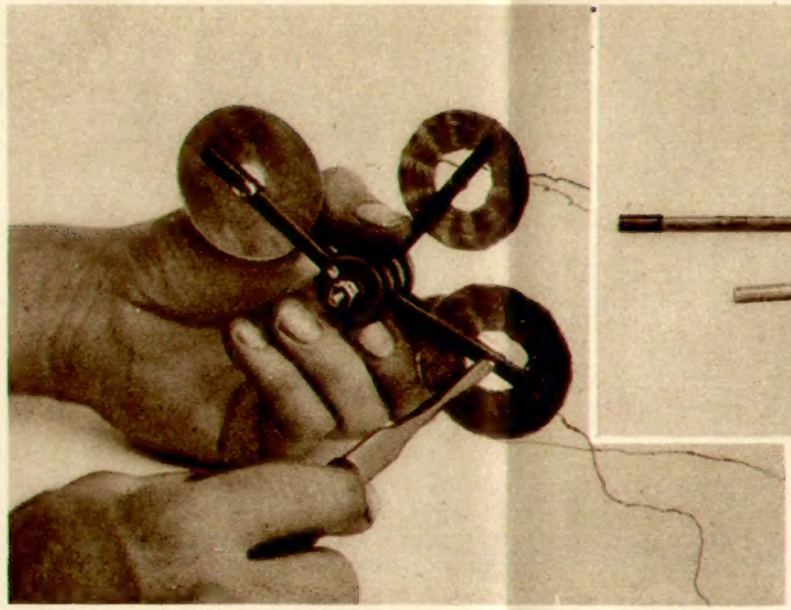


Fig. 11. Here are shown the two basket coils, forming the aerial coil and reaction coil, and the spade-tuning plate used in the receiver

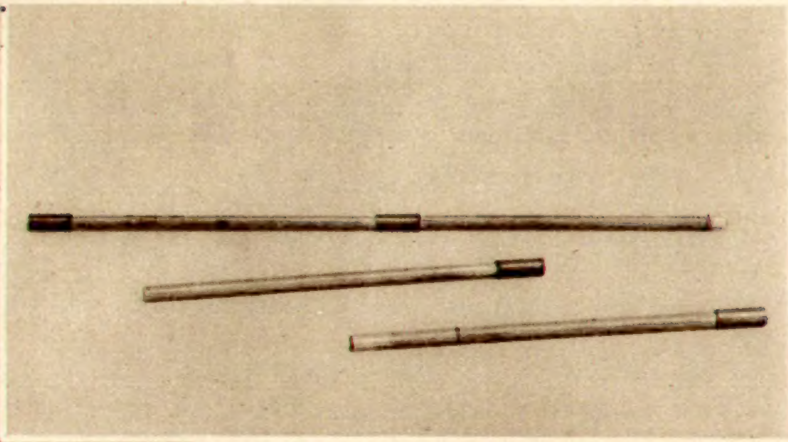


Fig. 12. Four telescopic rods, such as those illustrated here, are used to make the frame aerial

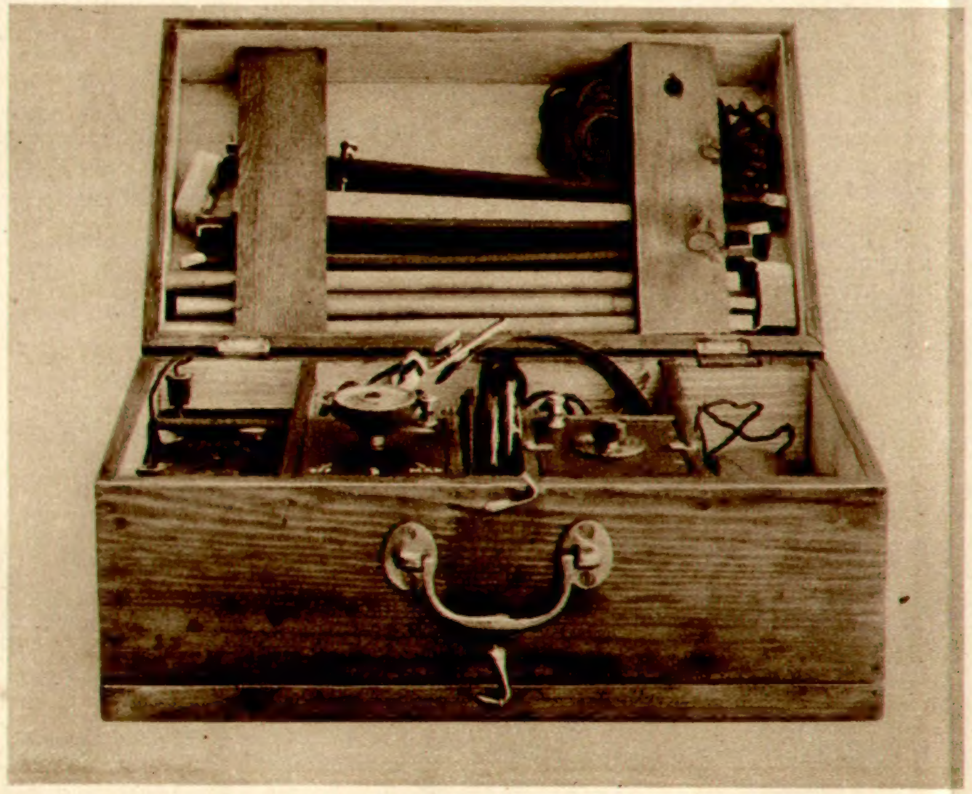


Fig. 13. Completed set built with Myers valves. The frame aerial packs in the lid of the case, which also holds batteries and telephones

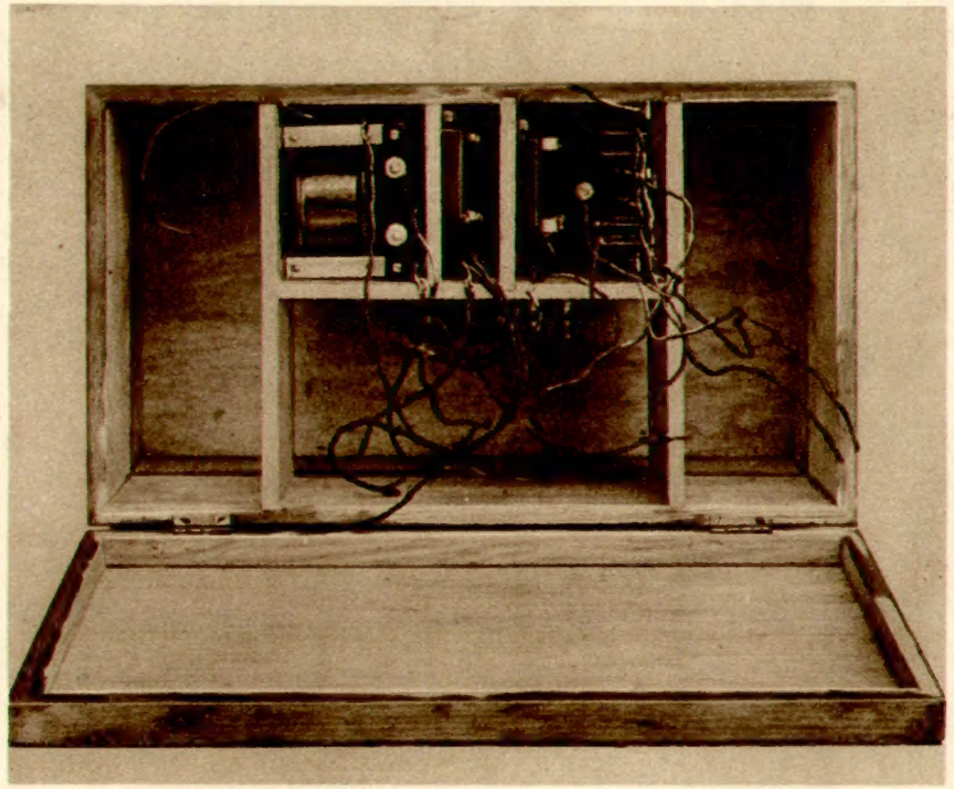


Fig. 14. Here are shown the compartments for the valves, grid leak and condenser, filament resistance and transformer, and the aerial and reaction coils

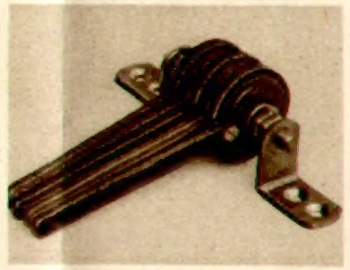


Fig. 15. Detail of the special holder for basket coils and spade tuner

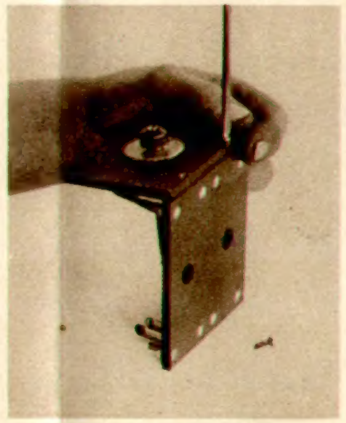


Fig. 16. Making up the valve panel and grid-leak support

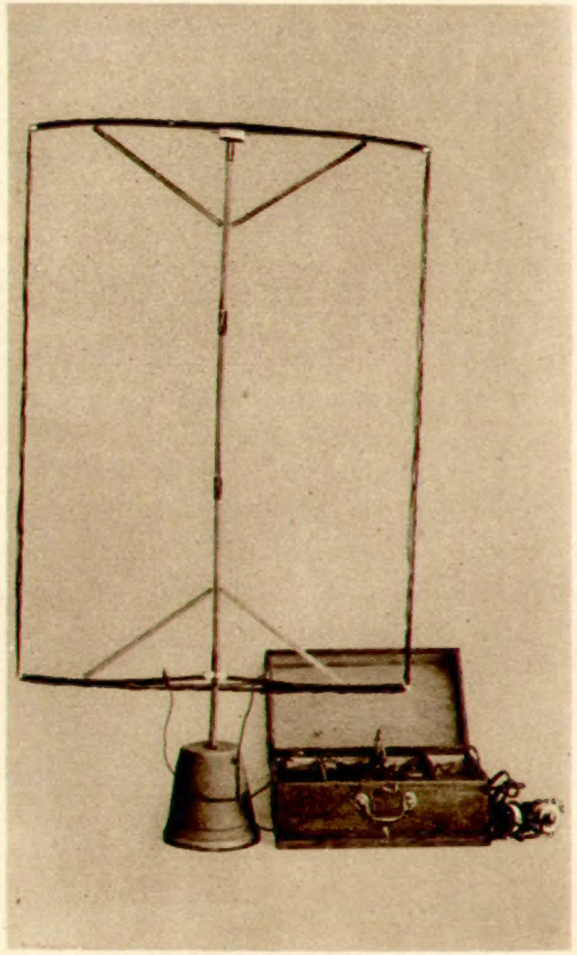


Fig. 17. Completed set erected and laid out for use indoors. Note the neat frame aerial

VALVE RECEIVING SETS: SUCCESSIVE STAGES IN THE BUILDING-UP OF A NOVEL AND EFFICIENT TWO-VALVE PORTABLE RECEIVER, USING MYERS VALVES

From photographs of a set specially designed and constructed for Harmsworth's Wireless Encyclopedia

To Our Readers

SOME little time ago, in connexion with one of our other fortnightlies, a schoolmaster in Australia wrote to me that he was so delighted with the various part publications issued by this house that he felt he could only express his opinion by saying " If it's Harmsworth's, it's good."

AS the editor who has been responsible for so many of these works I was greatly pleased to have this very high testimony to their usefulness, and I am glad to say that my readers in all parts of the world are good enough to leave me in no doubt as to the high value they place upon HARMSWORTH'S part publications, by writing letters of appreciation, suggestion or helpful criticism.

OUR WIRELESS ENCYCLOPEDIA, the very first work of its kind to be published—immeasurably more comprehensive than any of the multitudinous books on the same subject that have appeared in this country or in the United States—has differed from most of our part publications in being limited to one, and that a highly specialized, subject. Yet I think we have succeeded in presenting every feature of Wireless as it is known to-day with the most illuminating detail and in a manner so attractive that even stark technicalities have become interesting.

WITH the completion of the WIRELESS ENCYCLOPEDIA and the concluding of the very famous HOUSEHOLD ENCYCLOPEDIA, my readers will rightly suppose that we are likely to be coming before them at an early date with new enterprises. Within a very few weeks they will see announcements of another HARMSWORTH fortnightly, and although it will have no remote association with Wireless, it will probably attract many of those who have been subscribing to the popular work, in the concluding part of which these notes appear.

THIS new publication, the title of which is to be HARMSWORTH'S HOME DOCTOR, will be found of engrossing interest to all who are in search of physical fitness. Within recent years there has been a very definite and growing movement in favour of raising the physical standard of the nation, and nothing that has been attempted in a literary way so far can be said to have offered anything comparable with the practical help provided in HARMSWORTH'S HOME DOCTOR.

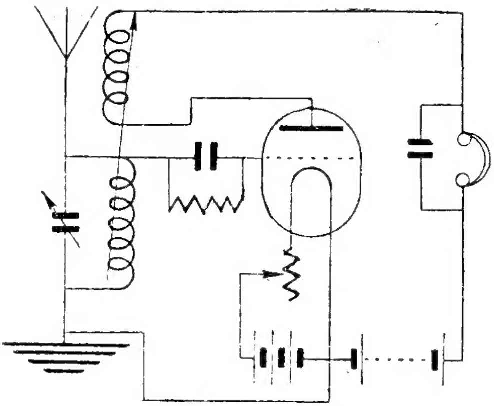
IT is an entirely new work, every line of it written by eminent and experienced general practitioners and specialists in medicine and surgery and physical culture. Utterly free from all pruriency, splendidly illustrated with thousands of new and specially taken photographs, there is really no one who can fail to benefit by a study of its pages, so that I anticipate for it a very wide circulation. All Wireless enthusiasts who know what we have done for them in the WIRELESS ENCYCLOPEDIA—the thoroughness, the accuracy, the suggestiveness of it—can be assured that in the larger sphere of personal health and fitness, into which so many thousands of considerations enter, we shall provide in HARMSWORTH'S HOME DOCTOR a work equally detailed and vastly wider in its scope.

J. A. H.

Look out for Part I on October 14th.

the wood of the baseboard to avoid risk of their short-circuiting.

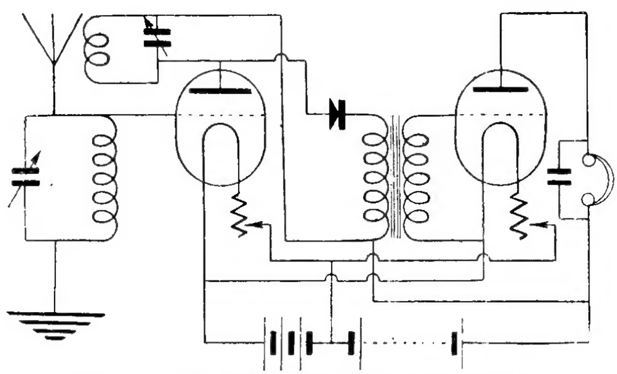
The intermediate connexions between the units, when needed, are best made with No. 16 gauge insulated copper wire. A small stock of these connecting wires can be cut to lengths of 6 or 7 in., and kept on hand with ready prepared bared ends to save time. A convenient number of units, enabling practically any two-valve circuit, with or without crystal detector, to be put up, should comprise two tuning units, two valve units, one low-frequency transformer unit, one crystal detector unit, one telephone connexion unit, one grid leak and condenser unit, and one or two fixed condenser units, although a greater or less number can be built at the start, according to circumstances.



REACTION WITH UNIVERSAL UNITS

Fig. 22. This circuit diagram illustrates the connexions for the single-valve set with reaction, shown in Fig. 21

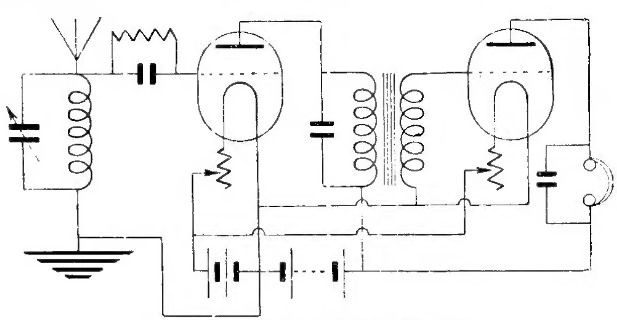
Some possible combinations are illustrated in Figs. 17 to 24. Fig. 17 shows three units set up to form a complete crystal detector, while Fig. 19 shows the theoretical circuit diagram. It will be noted in this case that as no batteries are needed, one of the bus bars can be used for the aerial connexion and the other for the earth connexion, the only bridging wire that is needed being that between one side of the crystal detector and the telephone unit, the telephones themselves being attached to terminals thereon. In use a coil of appropriate value should be plugged into the coil holder. For ordinary broadcast reception on an average aerial, this may conveniently be a No. 2½ Burndept or a 35 or 50 honeycomb. The crystal is adjusted to a sensitive spot, and the signals tuned in by the rotation of the condenser knob in the usual way.



TWO-VALVE SET WITH UNIT COMPONENTS

Fig. 23. In page 2170 is shown the complete two-valve universal set with crystal detection, for which this is the circuit

A set up for a single-valve set is shown in Fig. 18, and the corresponding theoretical circuit diagram is given in Fig. 20. In this case the length of the baseboard permits the accumulator and high-tension battery to stand at either end, and the aerial and earth connexions are made direct to the coil holder, the bus bars being used for the high- and low-tension battery current distribution purposes, as already explained. The units employed are one tuning unit, grid leak and condenser unit, and the valve and telephone units.



NORMAL TWO-VALVE CIRCUIT

Fig. 24. When the experimenter wishes to construct an ordinary two-valve set he will find that it is quickly set up with the universal unit set

The only bridging wires in this case are those from the aerial side of the plug-in coil holder to one side of the grid leak and to the grid terminal of the valve unit. Another bridging connexion is made between the anode terminal of the valve unit and one side of the telephone unit.

If it be desired to make a single-valve set with reaction, the same units are employed, with the addition of a second tuning unit, which in this case is used for reaction purposes. This arrangement is shown in Fig. 21, and the corresponding theoretical circuit diagram in Fig. 22.

It will be noted in this case that the units are turned around so that the two coils are facing each other, the variation of coupling being effected by sliding the aerial tuning unit nearer to or farther from the reaction unit, thus providing the requisite adjustment in an efficient manner.

Another system consists of a stage of tuned-anode high-frequency amplification with reaction on to the aerial. Rectification is by a crystal detector, which is followed by a stage of low-frequency amplification. The circuit arrangements are shown in the theoretical circuit diagram in Fig. 23.

Many other circuits can be put up without altering the units, their number being practically only limited by the time and patience of the constructor.

V

VACUUM. Space that has been emptied of all ponderable matter. In wireless the term is most generally used in connexion with valves and vacuum tubes. There is no such thing as a completely exhausted vacuum vessel, though a very high state of rarefaction may be produced by several means.

It is important in wireless, as well as in the study of the phenomena of vacuum tubes, that the vacuum should be maintained constant, or should be controllable in some way. Valves which contain any amount of gas give very different results from those which are almost entirely free from gas. A valve which contains a fairly large amount of gas is said to be soft, and one in which the vacuum is high is said to be hard. Nearly all the early valves, including the famous Round valve, were soft vacuum valves. *See* Round Valve; Valve.

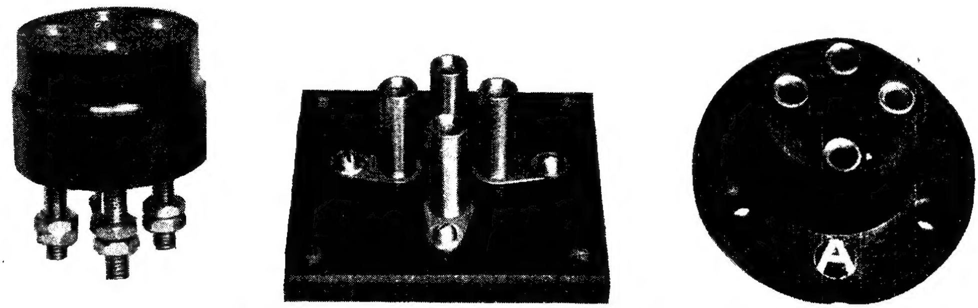
VACUUM TUBE. Glass tube made in various shapes and filled with air or gases at pressures below that of the atmosphere. The pressure in any particular tube, as the cathode ray tube, may be considerably below that of the atmosphere, *i.e.* the vacuum may be high. There are many types of vacuum tubes. All have two or more electrodes fused through the glass of the tube so that electric charges may be passed through the tube. The effect of a high potential in a rarefied gas is to cause the interior of the tube to glow, the character and colour of the glow varying, naturally, with the nature of the contents.

The investigation into the character of the glow led ultimately to the discovery of X-rays and other rays, and the study of the rays now known to be given off when the tube is electrically excited has led to many further discoveries which have a most important bearing not only on an understanding of the nature of electricity, but also on the ultimate constitution of matter. *See* Cathode Ray Tube; Crookes's Tube; Electron; Geissler Tube; Ultra-violet Rays; Valve.

VALLAURI, GIANCARLO. Italian wireless authority. Born in Rome, 1882, he was educated at the Polytechnic School in Naples, making a special study of electricity. He was appointed lecturer in succession to the Polytechnic schools of Padua, Karlsruhe and Naples, and adviser to many commercial electrical firms. He inaugurated in 1912 at Naples one of the earliest courses in wireless telegraphy. In 1916 he was placed in charge of the Institute of Electricity and Wireless Telegraphy of the Italian Navy, and shortly afterwards was appointed professor of electrotechnics at the University of Pisa, and in charge of the supervisory work for the great wireless station of Coltano-centre. He is the author of a frequency doubler which employs a special three-leg transformer with two primary windings and two secondary windings on each of the two outer limbs and a common magnetizing winding on the central limb. Vallauri has made a special study of ferro-magnetic phenomena, and has published a series of papers on ionic valves and other subjects connected with wireless.

VALVE HOLDER. Term used to describe a small component for the reception of a thermionic valve used in wireless work. The bulk of the valves employed by the amateur are of the standard four-pin,

three-electrode pattern, and the holders are generally composed of ebonite, either moulded or machined from the solid. In some cases ebonite substitutes or other compositions are employed. It is usually considered that the genuine ebonite holders are to be preferred on the score of good insulation.



TYPES OF VALVE HOLDERS IN COMMON USE

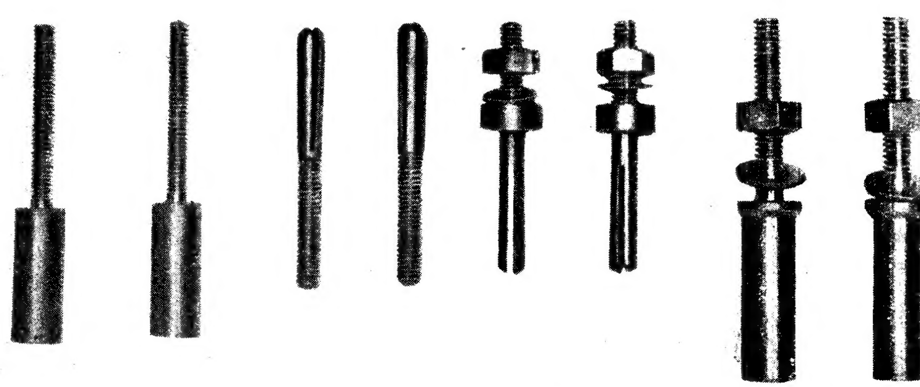
Three varieties of ordinary thermionic valve holders are shown here. Left to right they are: the ordinary solid type, panel-mounting type, and the flanged variety, also for panel mounting

Courtesy Peto-Scott Co., Ltd.

Three useful types are illustrated. That on the left is the ordinary solid pattern, in which a circular piece of ebonite supports four valve sockets provided with nuts wherewith to fix the holder to the panel, and also to receive the ends of the connecting wires. On the right is a standard flange-type holder, the plate or anode terminal of which is clearly marked with the letter A. Connexions are made by soldering to the underside of the sockets, the wires passing through grooves formed in the flange.

The middle pattern has been designed to reduce capacity losses as much as possible, and consists of an ebonite plate with four sockets mounted upon it, each socket having a single metal contact to which connexions are made by means of round-headed screws and washers. Valve holders for Myers valves, and some of the Marconi and other makes which are arranged to be mounted parallel with the surface of the panel, usually employ four separate angular strips of metal, suitably shaped in accordance with the shape of the pins or terminals on the valve itself. *See* under the titles of the particular valves in this Encyclopedia, and also under Portable Receiving Set; Valves.

VALVE LEG. Name given to a small but very useful component chiefly employed by the amateur in the construction of various pieces of apparatus in which the pins are employed in conjunction with sockets to make a form of readily



VALVE LEGS FOR USE IN WIRELESS CONSTRUCTION

Above are illustrated various common types of valve legs and their corresponding sockets. The amateur will find these extremely useful in construction for quick contacts

detachable connexion. Valve pins and sockets as usually supplied are illustrated. Four pins are shown in the centre. Those which are simply screwed are usually employed in valve caps and other small places. When provided with a collar and a washer they can be attached to ebonite plates and other devices for the construction of various plug-in contacts.

VALVE OSCILLATOR. Name given to a reaction or regenerative circuit so arranged and tuned that the coupling between the anode and the grid circuits is sufficient to maintain a continuous interaction. *See* Armstrong Circuits ; Oscillator ; Reaction ; Regeneration.

VALVE PANEL. Term used to describe a panel on which are erected the various components for the reception of valves in a wireless set. In large transmission stations the expression "valve panel" is often applied to composite structures used for a somewhat similar purpose.

VALVE PINS. Name sometimes applied to the peg or terminal attached to the cap of a valve. *See* Valve Leg.

VALVE RECEIVING SETS: THEIR USES AND CONSTRUCTION

How the Amateur may Construct Two Efficient Valve Sets

Many valve receiving sets have been described in this Encyclopedia, and they cover a wide enough range to suit any requirements of an amateur. The reader should consult all those headings dealing with particular sets, as Armstrong Receivers; Flewelling Receivers, etc., and also such cognate entries as Amplifiers; High-frequency Amplifier; Regenerative Sets, etc. For further information see such general headings as Tuning; Valves, etc.

Here is described the making of a simple two-valve and crystal set and also a set containing Myers valves, which have the advantage of being far less fragile than the ordinary valve.

The amateur-constructed set illustrated in Fig. 1 was designed with a view to economy in cost of construction and simplicity. It is a straightforward circuit of one high-frequency valve, a crystal detector, and one low-frequency valve, with reaction on the aerial tuning inductance. It is effective in operation and brings in, near 2 LO on a poor aerial, the local broadcasting quite loudly enough for good strength in the loud speaker (12 miles), whilst Birmingham, Bournemouth, Radiola, the Ecole des Postes et des Télégraphes and the Eiffel Tower come in excellently on the headphones.

Fig. 1 shows the general arrangement. It will be noticed that all terminals and fittings requiring insulation are mounted on pieces of ebonite, whilst the panel itself, measuring 13 in. by $9\frac{1}{2}$ in., is of three-ply wood, large holes being cut so that all terminals, etc., may be clear. The three-ply should not be less than $\frac{1}{4}$ in. thick, and if faced with hardwood will polish up well. A strip of ebonite $10\frac{1}{2}$ in. by 1 in. is cut for the terminals, spaced $1\frac{7}{8}$ in. apart.

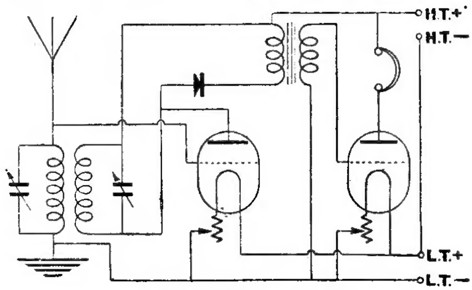
The valve sockets are mounted on similar ebonite $1\frac{1}{2}$ in. square. The telephone terminals are on a strip 4 in. by 1 in., whilst the two valve sockets to accommodate the tuning coil are mounted on a piece similar to that for the valve holders. The arm for the reaction coil is 4 in. long by 1 in. wide. All these pieces may be seen in Fig. 2. The crystal detector is purchased ready made mounted on ebonite. The two terminals may be removed and a pair of contact studs substituted in order that they may project well through the panel. Similar ebonite parts may be purchased ready assembled, and save the time of cutting and drilling.

The ebonite portions being prepared or purchased, the panel may be drilled with large holes for all metal parts to clear, which, with the exception of the valve sockets, will be $\frac{1}{2}$ in. in diameter. It will be convenient at this stage to prepare the containing box, which is 6 in. deep and 13 in. by $9\frac{1}{2}$ in., inside measurements. The box illustrated is cleaned up at the corners and edges and covered with imitation leather paper. A small fillet is fastened $\frac{1}{4}$ in. from the top edge, and the panel may be placed in position.

Two variable condensers are necessary, one for the aerial tuning of ·0005 mfd. capacity and one for the anode of ·0003 mfd. capacity, though two of ·0005 mfd. value will give somewhat sharper anode tuning. The filament resistances may be of standard make, although those illustrated simply consist of two disks of wood $1\frac{1}{2}$ in. in diameter and $\frac{3}{4}$ in. thick, around which is wrapped a piece of fibre 1 in. wide. Upon this is wound three yards of No. 24 gauge Eureka resistance wire, the contacts and stops being fashioned in the usual way, as described under the heading

Filament Resistance (*q.v.*). The low-frequency transformer needs no comment and should be fitted to the panel as indicated.

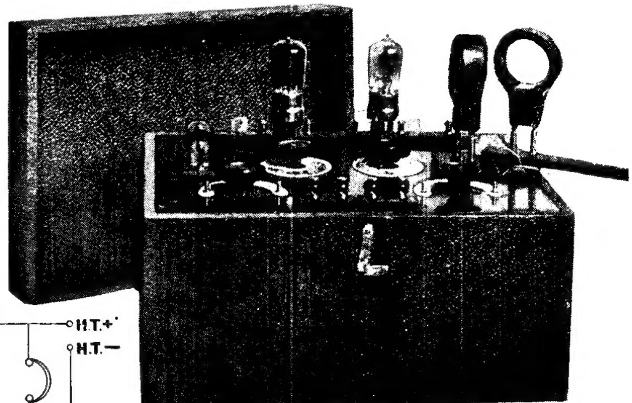
Care should be taken in setting out the various components to see that a reasonable margin is left all round, as it is of considerable assistance in wiring to be able to turn the panel completely



CIRCUIT DIAGRAM

Fig. 2. Here is given the theoretical circuit of the two-valve and crystal set shown in Fig. 1

upside down, the box then forming a protection for components fastened to the front while wiring.



COMPLETE TWO-VALVE AND CRYSTAL SET

Fig. 1. In this set is employed a stage of high frequency and one of low, with a crystal as rectifier and detector. This set works a loud speaker at 12 miles from a broadcasting station

The wiring, shown in Figs. 4, 5 and 6, is carried out with stiff tinned copper wire, which should be cut and bent to shape before soldering.

The set should operate without difficulty. Having joined up the batteries, connected the telephones and plugged in the coils, which may be of standard pattern honeycomb, basket or the like, the anode coil

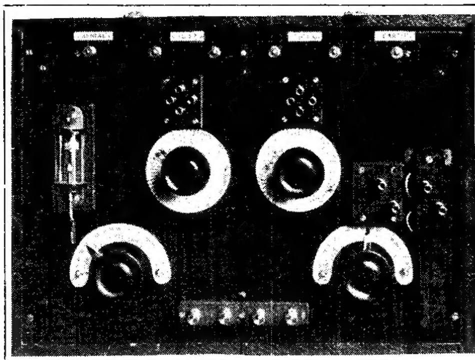


Fig. 3. Front view of the high-frequency, crystal and low-frequency set, showing the components in position and the various terminals for the connexions

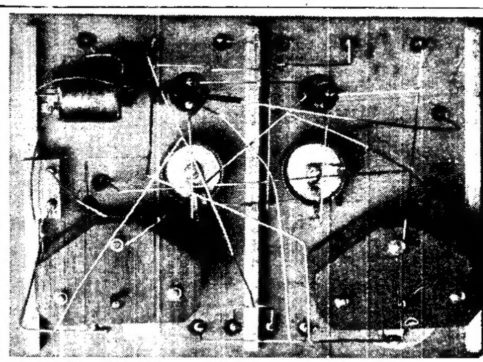


Fig. 4. Back of the panel, showing the wiring. Leads from the movable reaction coil are fastened by two contact studs mounted on ebonite, to which the stiff leads are soldered

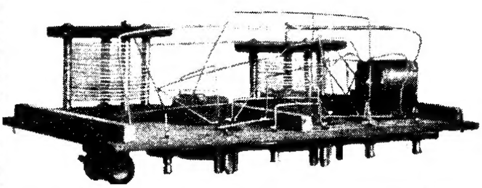


Fig. 5. Transformer side of the panel seen from the back. This view will help to make the wiring clear

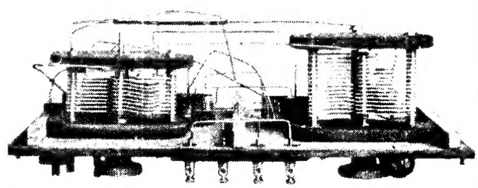
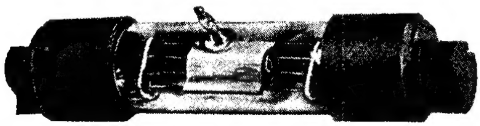


Fig. 6. Condenser side of the panel, showing the connexions in the wiring of the telephones and loud speaker

HOW THE VARIOUS STEPS IN THE CONSTRUCTION OF THE TWO-VALVE SET ARE CARRIED OUT



MYERS VALVE

Fig. 7. This type of valve is used in the construction of the set shown in the following illustrations. It is of unusual construction and practically unbreakable

should be swung out at right angles to the aerial coil. The two condenser knobs should now be slowly revolved.

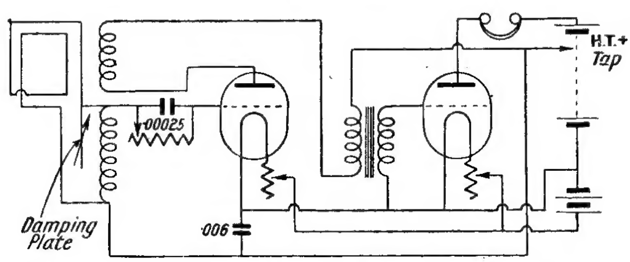
When a signal is heard, find the best positions for condensers and filament resistances. Now turn out the high-frequency valve and readjust the crystal to the loudest signals. The high-frequency valve may now be relit and adjusted to the best results. If it is desired to use reaction, the anode coil may be carefully brought closer to the aerial coil, readjusting both condensers as may be necessary. With careful adjustments a very great increase of signal strength may thus be obtained, care being taken to loosen the coupling as soon as any hissing or whistling is heard.

The Myers valves, Fig. 7, are made in two patterns for dry battery or accumulator operation, and are known as dull or bright emitters, according to the voltage. They are neat, compact, efficient in use and admirable for a portable set such as that shown in Fig. 13 on the photogravure plate.

The circuit of this portable set is given in Fig. 8; it is a modified Flewelling, and has a stage of low-frequency amplification. The case shown dimensioned in Fig. 9, is $\frac{1}{4}$ in. thick with three-ply wood sides, is hinged on both sides and is provided with a handle for carrying. The two smaller central compartments, Figs. 13 and 14 on the plate, are occupied respectively by two Myers valves, a variable grid leak and condenser and the filament resistance and low-frequency transformer. The space between is occupied by the aerial coil, spade tuning plate and reaction coil separately adjustable, and as illustrated in Fig. 11 on the plate.

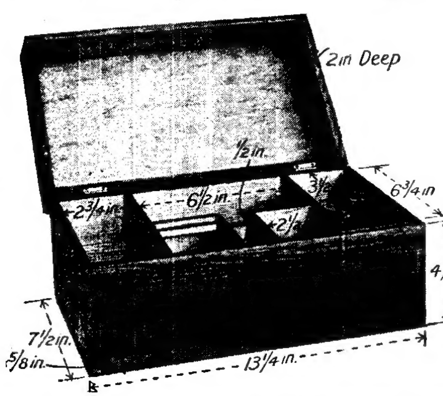
Details of the holders are given in Fig. 15; the angle brackets are screwed to the face of the case at the notched part seen in Fig. 18. The mode of mounting the valves and grid leak on an angular ebonite plate is clear from Fig. 10 on the plate. It should be noted that the valves are set with the red caps uppermost.

A similar angular piece is made and carries the filament resistance; the low-frequency transformer is screwed to the case side beneath the resistance coil. The various condensers are placed on the sides of the partitions and the whole is wired with flexible silk-covered wire.



MODIFIED FLEWELLING CIRCUIT

Fig. 8. Theoretical circuit showing the connexions to be made in the building of the Myers valve set



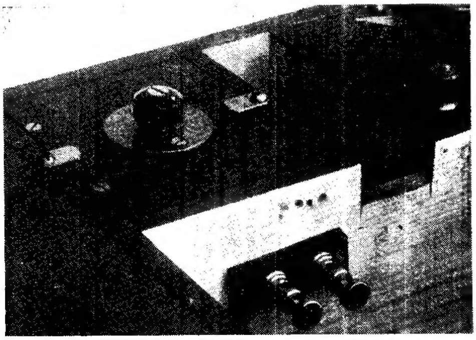
CABINET FOR THE MYERS VALVE SET

Fig. 9. Here the case for the set is illustrated. For the constructor's assistance all the main dimensions are given

The Myers valves are supplied with a set of parts for the construction of the holders, which consist essentially of angular plates of springy metal. These have to be bolted to the ebonite panel, and to fit properly the fixing screw holes should be drilled to accord with the paper template.

One way to do this is shown in Fig. 19. The paper is placed on the top of the panel and secured with a trace of some adhesive, and the holes marked by punching with a centre punch. In the present set the valves are set side by side, and consequently all the holes should be similarly marked

and drilled. The angle pieces are then screwed and nutted in place and the screw heads well countersunk below the surface, the holes being filled with insulating wax as shown in Fig. 20 This is best melted in a small saucepan and



INTERIOR CONSTRUCTIONAL DETAILS

Fig. 18. The ebonite angle-piece in the left-hand compartment carries the grid leak and Myers valves as seen in Fig. 10

the surplus scraped off with the end or side of a blunt chisel.

This panel forms an inner lining to the valve chamber in the case, the top being enclosed by another smaller panel, to the centre of which is fixed the variable grid leak in the usual way. This panel is then secured to the valve panel by small brass screws passed into the edge of the valve panel, as shown in Fig. 16 on the plate. The whole is then secured in place in the case by means of two small turnplates of brass (Fig. 18)

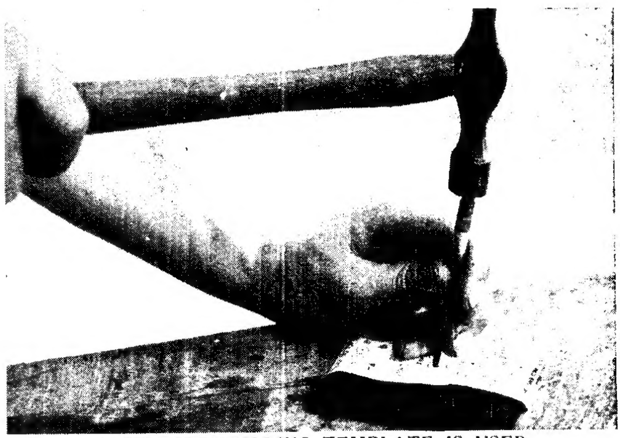
The other panel is made in a similar manner and placed in position in the other partition in the case, but as the space is limited, select a filament resistance that is thin and small in diameter, so that it will fit easily beneath the panel, as shown in Fig. 23. Tuning is effected in this set by the use of basket coils, which can be wound as described in the article on Basket Coils (*q.v.*), and the value should be that most appropriate to the local station's wave-lengths, so that when in use the spade will not have to be very closely coupled to tune the set.

The reaction coil is a similar basket coil, and both are mounted between two strips of thin ebonite screwed to the edge of ebonite disks about an inch in diameter, as is shown in Figs. 11 and 15 on the plate.

The disks should be knurled on the outside and mounted on a short length of screwed rod, each disk being separated by a spring washer. The rod is supported on small angle plates, as shown in Fig. 15 on the plate, and secured to them, when the holder is fixed to the case, by means of lock nuts.

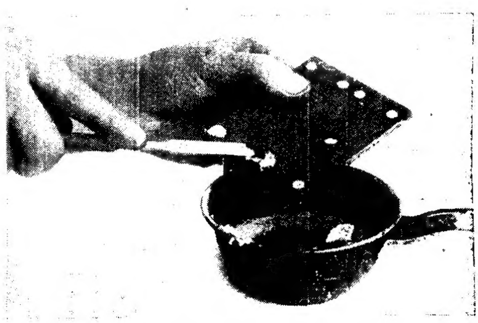
The spade is a simple disk of aluminium, and secured, like the coils, by a central screw passed through the two blades on the holders.

Owing to the restricted space it is advisable to carry out the bulk of the wiring with single insulated flexible wire. This is readily done by drawing out the panels until the terminals are accessible and connecting the wires with nuts or by soldering. The high-tension battery



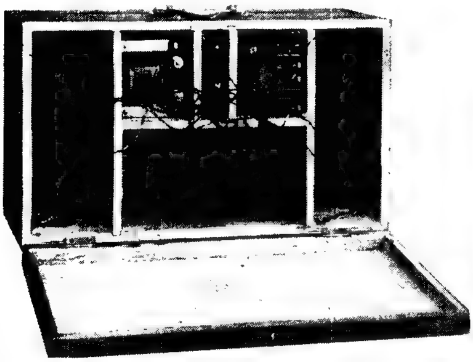
HOW THE DRILLING TEMPLATE IS USED

Fig. 19. Here is shown the method employed with the Myers valve-drilling template when marking out the panel



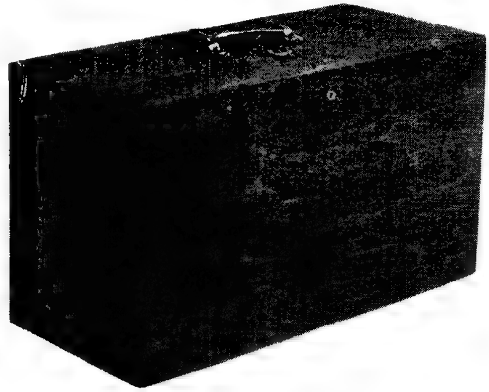
REMOVING SURPLUS WAX

Fig. 20. After filling up the screw holes in the panel the surface wax is scraped off the underside



THE SET COMPLETELY WIRED

Fig. 21. In the building of this set the making of connexions is greatly simplified by using flexible wires



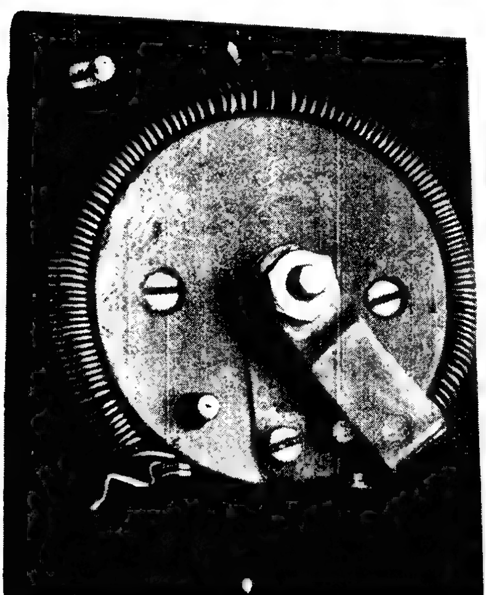
COMPLETE SET CLOSED

Fig. 22. When it is packed up the Myers valve set has a very neat and compact appearance. The weight is not heavy

connexions terminate in wander plugs, which should be of different colours. They are seen to the left of Fig. 21, where they are shown in the high-tension battery compartment. The two connecting wires for the low-tension battery terminate in the opposite compartment and may have spade terminals.

The aerial may be a simple frame with collapsible members, which can be packed into the lid of the case.

The frame is composed of four telescopic rods about 10 in. long, with a brass ferrule at one end, as shown in Fig. 12 on the plate. Two ebonite strips, about 1 in. wide and 9 in. long, are hinged to a small piece of hardwood, which has a hole through the centre for the passage of the central rod.



FILAMENT RESISTANCE

Fig. 23. It is important that this component should fit centrally on account of the very limited space available for it

The ends of the ebonite strips have little strips of leather which hold the aerial wire in place. The lower of the strips, as shown in Fig. 17 on the special plate, has terminals for the two connexions from the frame aerial to the earth and aerial terminals on the set respectively. The aerial wire is preferably Litzendraht. Five or six turns are taken around the frame while it is laid flat on the workbench, and the ebonite strips supported in position by nails or blocks.

When the wires are wound and connected four struts of thin wood are cut to span the angle between the ebonite strips and the central rod, and are fitted into notches cut for the purpose of holding them in place, as in Fig. 17, where the aerial is held in an upright position by placing it in an inverted flower pot.

The frame aerial, batteries and telephones all pack into the case, as shown in Fig. 22. The frame is set up by pressing the end of the rod into the ground and connecting the set as shown in Fig. 10 on the plate, although better results are sometimes found by suspending the frame from a branch of a tree by means of a thin string, and using temporary longer connexions to the set. Tuning follows the system detailed under the heading Super-regenerative Set. *See* Portable Receiving Set.

VALVES EMPLOYED IN WIRELESS RECEPTION

By E. V. Appleton, M.A., D.Sc.

The choice of suitable valves to employ in a receiving set requires careful consideration, as certain circuits call for particular types, and the experimenter should study this detailed account of the different varieties that are available. Other references to the subject will be found in the constructional hints on different types of receivers and under names of specific valves. See also Valves for Transmission

In choosing a three-electrode valve for use as an amplifier or detector in a wireless receiver we are assisted by being able to predict its performance to some extent by an inspection of its static characteristics. These characteristics are curves illustrating the relations between the currents between the various electrodes and the potentials applied to the electrodes.

Before considering the various functions of a valve in a receiver it is therefore of interest for us to consider briefly the way in which the modern valve is designed.

The modern three-electrode valve consists essentially of a highly evacuated vessel containing a thermionic cathode (usually in the form of a filament which can be heated by passing a current through it), an anode and a current-controlling electrode, which generally takes the form of a wire mesh or grid, placed between the cathode and anode. It is essential for stability and constancy that the valve should be highly evacuated, and that the metal electrodes and the glass walls should be free from gas.

Modern valve technique in manufacture has been developed to such a stage that the ordinary hard receiving valve contains gas at a pressure as low as 1/100,000 mm. of mercury. In this way remarkable constancy of electrical action is attained.

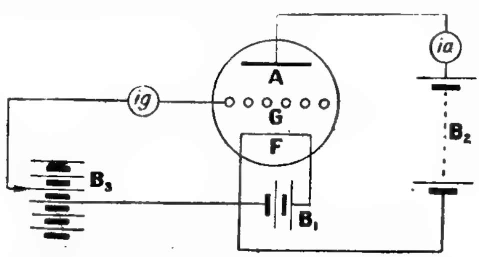
In the design of the three electrodes of a valve, three factors are of importance and require specification. In the first place we wish to specify the total amount of electron current emitted by the filament when a certain power is dissipated in it. This will depend on the size of the filament and also on the nature of the material of which the filament is made. Secondly, we wish to specify the amplification factor (K) of the tube so that we may predict its performance as an amplifier. The amplification factor depends only on the geometrical shape of the electrodes. Thirdly, we wish to specify the internal resistance (R) of the tube, which depends on both the electron emission and the geometry of the electrodes.

These three quantities may, of course, be determined by an inspection of the static characteristics mentioned above. We can best realize their significance by a brief survey of the physics of the action of a three-electrode valve.

Fig. 1 shows a valve diagrammatically. Here F is the filament, heated to incandescence by current from the battery B_1, G represents the grid or perforated electrode, while A is the anode and has a continuous surface. The anode is normally maintained at a positive potential with respect to the filament by the high-tension battery B_2, while the potential of the grid can be made positive or negative with respect to the filament by means of the battery B_3.

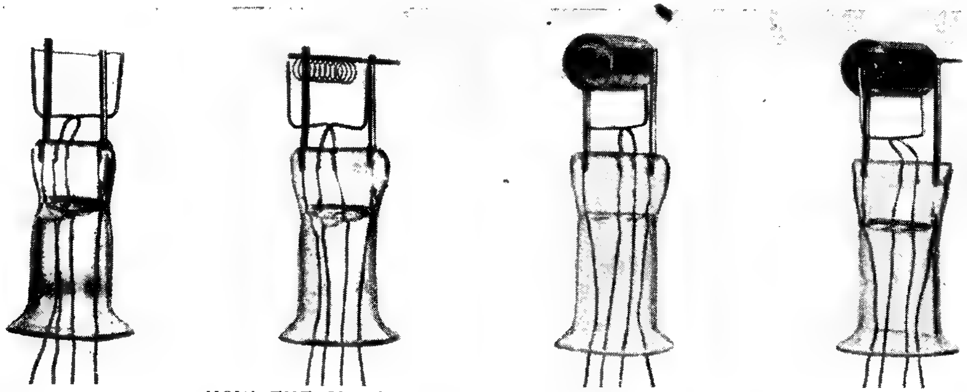
Since the positively charged anode attracts the negative electrons emitted by the filament, some of the latter in normal cases pass through the holes in the grid, arriving at the anode, so that an anode current (*ia*) is registered. But the journey of these electrons is made difficult by the repulsion that they exert on one another. For example, an electron just leaving the filament is repelled by the electrons which have got some distance on their journey towards the anode. The result is that all the electrons emitted by the filament are not collected by the anode unless the latter is very strongly positively charged, in which case a large anode battery (B_2) would be required.

We may, however, use an anode battery of medium voltage, which alone will cause only a fraction (*e.g.* a quarter to a half) of



THERMIONIC VALVE THEORY

Fig. 1. This diagram illustrates the working of a valve. F is the filament, G the grid and A the anode



HOW THE MARCONI-OSRAM R VALVE IS ASSEMBLED

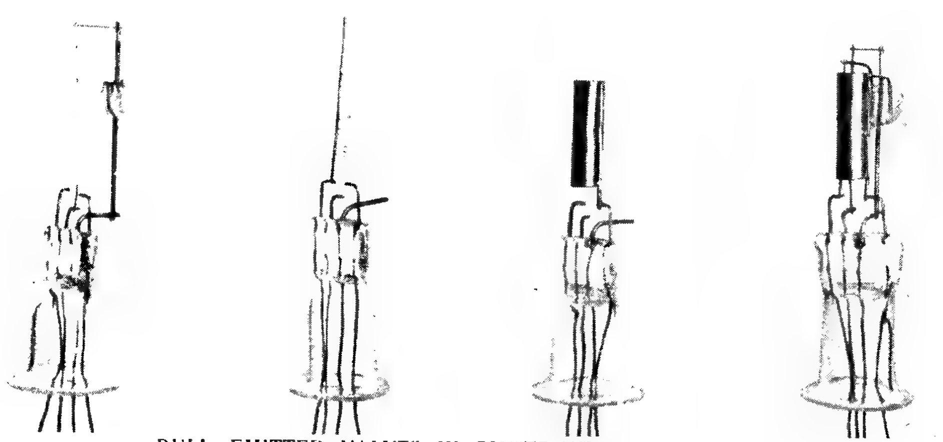
Fig. 2. On the left are shown the supports of the electrodes with the filament attached. It will be seen that the outer supports are for grid and anode. The grid is seen in position in the next illustration, while the anode is shown attached to its support in the third. On the right the construction is at the stage prior to fitting inside the bulb

the electrons to reach the anode, and use the grid to enable us to control the amount of electron current the anode receives. For definiteness let us suppose that the action of the anode is such that an increase of 20 volts in anode potential is required to increase the current to the anode by one milliampere.

Further, let us suppose that we now make the grid slightly positively electrified with respect to the filament by means of battery B_3. Since the grid is nearer the filament than the anode, only a comparatively small grid potential is necessary to give it a large positive charge, and so give the electrons near the filament the extra pull necessary to get them started on their journey to the anode.

These electrons very soon acquire a very high velocity (of the order of 10,000,000 centimetres per second) and, although they are all attracted by the positive charge on the grid, practically only the ones that hit the grid wires directly are caught by the grid, the remainder having sufficient momentum to enable them to get through the holes, after which they are caught by the anode.

The grid is therefore efficient in attracting the electrons but inefficient in catching them. Thus if we increase the grid potential we find the current to the



DULL EMITTER VALVES IN CONSTRUCTION: THE D.E.3

Fig. 3. An interesting feature of this valve is that the rod supporting the upper end of the vertical filament has a globular piece of glass attached. Into this glass two wires are fused to support the tops of the grid and anode, and the threefold purpose of this rod is seen on the right. The central illustrations show the fixing of grid and anode

anode is increased, and in a typical valve we may find that this increase of anode current may be of the order of one milliampere for 2 volts increase of grid potential. Comparing this with the figure mentioned above for the change of anode current with change of anode potential, we see that the grid has 10 times the control action of the anode current possessed by the anode itself.

The figure 10 here represents the amplification factor of the tube, which depends on the dimensions of the grid and anode. For example, the closer the grid wires are together, or the bigger the distance between the grid and anode, the greater the amplification factor. Mathematical formulae have been derived which enable us to calculate the amplification factor (K) from a knowledge of the dimensions of the electrodes, so that in most cases this quantity is known before the valve is exhausted.

The internal resistance (R_i) of the valve is the effective resistance between the filament and the anode for small changes of anode current. Thus in the example we have considered above the internal resistance is 20,000 ohms, since 20 volts anode potential charge produce a current change of one milliampere. Its value can be determined mathematically if the electron emission and the electrode dimensions are known.

The total electron current is determined by the size and value of the filament and the temperature to which it is raised by the heating current. In the older type of R valve filaments of "pure" tungsten (they actually contain a small percentage of thoria to increase the tensile strength) are used. The high temperature (2,300° to 2,500° absolute) required to give the necessary emission requires a comparatively large consumption of power in the filament (*e.g.* of the order of 3 watts), so that recently makers have developed filaments which are made of thoriated tungsten, and which give the same order of electron emission at much lower temperatures. Thoriated tungsten containing one to two per cent of thoria is used for most of these filaments.

It is only necessary to raise the temperature to 1,200° to 1,600° absolute to obtain the required emission, and this can be brought about by the expenditure of only ·18 watt in the filament. Filaments of platinum or platinum alloy coated with oxides (generally of the rare earths) are also made. These give a good emission of electrons at a very low temperature (1,000 to 1,200° absolute).

The grids and anodes of receiving valves are usually made of nickel, though molybdenum is sometimes used. The arrangement of these electrodes round the filament is usually one of three types, as follows:—

(*a*) Cylindrical type. Here the anode is a cylinder with the filament along its axis, while the grid is a helix of wire or a mesh tube between the filament and anode. This design is the most suitable one for quantity production.

Examples: Marconi-Osram R (Fig. 2), D.E.2, D.E.3 types (Fig. 3).

(*b*) Flat-plate type. Here the grid and anode consist of pairs of plane rectangular electrodes of grid and plate form respectively, placed on opposite sides of the filament.

Examples: B.T.H. B.4 valve, Western Electric Co. 102 D.W.

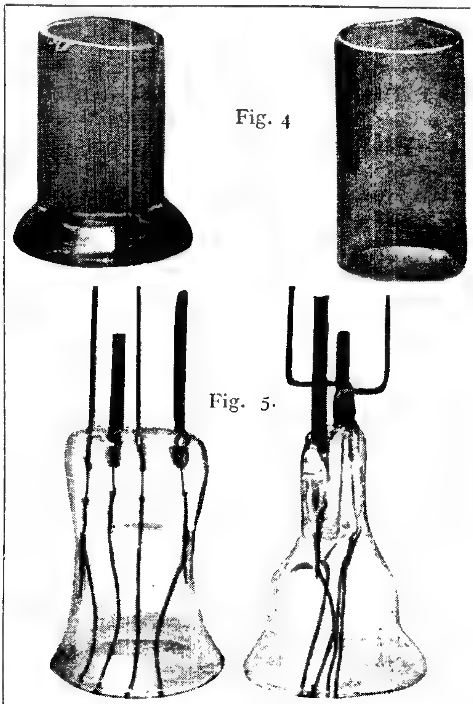
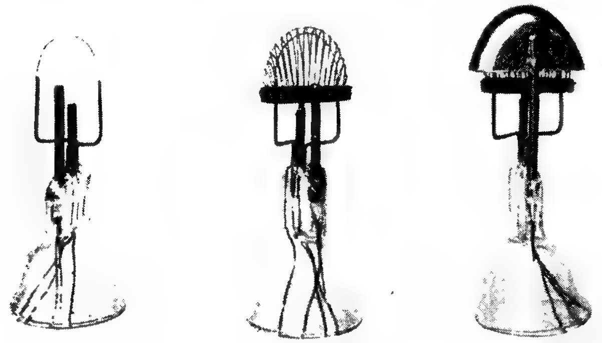


Fig. 4

Fig. 5.

Fig. 4 (above). Two preliminary stages in the construction of the Cossor valve are the cutting off of the foot tube to length and the bellying out of its end. Fig. 5 (below). Afterwards the tube is pinched to hold the electrodes. Then, as the right illustration shows, they are bent to position

HOW COSSOR RECEIVING VALVES ARE MADE



ERECTING FILAMENT, GRID AND ANODE OF COSSOR VALVES

Fig. 6. To the left of the illustration the hooped filament is seen; in the centre the grid is attached, and to the right the anode is seen completed

(c) Helmet-shaped type. The filament is a loop covered by a hood-shaped grid and an anode of similar shape.

Examples: Cossor P.1 (Figs. 4–7) and P.2 valves.

When the electrode dimensions of a valve have been decided on and the electrodes fixed in the glass bulb, the valve is then exhausted. The object aimed at is to obtain as high a vacuum as possible, and that in the process the filament should suffer as little as possible so that it may have a long life afterwards. The gases to be removed come from the electrodes and the glass bulb.

The glass is heated by placing the whole valve in an electric oven while pumping is carried out, but the electrodes have to be heated by electron bombardment. To this end the filament current is run at about its normal value, while a potential of 1,000 to 1 500 volts is applied between it and the anode, the grid being connected to the filament. In this way it is possible to bring the anode to a temperature not far from its melting point. While these operations are being carried out, the exhausting proceeds simultaneously until finally, by the aid of a mercury ejector pump, the pressure is reduced to about 10 to 5 mm. of mercury. The valves are then sealed off and are ready for ageing and testing. The Marconi-Osram method of doing this will be described here.

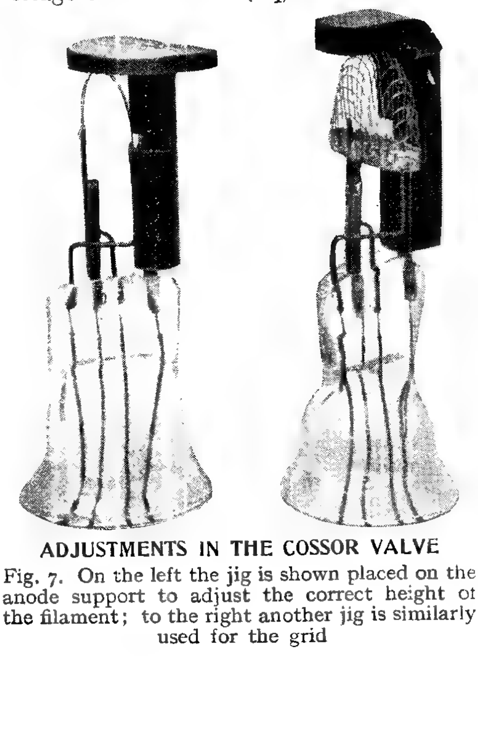
It is found that, however complete the regular bombardment and exhaust may be, there is always a subsequent clean-up of gas while the valve is run under normal conditions. Before testing, therefore, all valves are aged by running them for a limited time, varying from one to three hours, with normal filament current and grid and anode potential. The testing itself is very complete for every valve. The following tests are normally carried out.

(1) The insulation between the electrodes is tested. The resistance should be "infinite."

(2) The filament current and voltage to give correct electron emission are measured to see that they are according to specification.

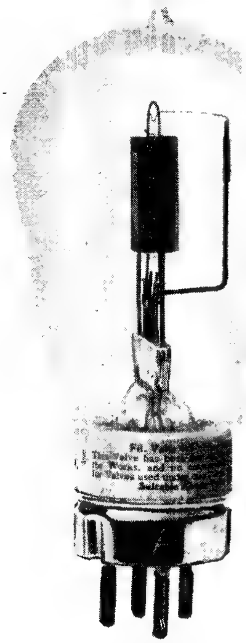
(3) The degree of vacuum is tested by measuring the amount of "backlash." In this test the anode is maintained at a positive potential high enough to produce ionization by collision if gas molecules are present. The presence of positive ions is indicated by the presence of a grid current when the grid is maintained at a negative potential with respect to the filament. If this positive grid current is greater than a certain amount the valve is rejected. This test for "softness" is one which the amateur can carry out easily himself.

(4) The slope of the anode current-grid voltage characteristic (K_1) is found



ADJUSTMENTS IN THE COSSOR VALVE

Fig. 7. On the left the jig is shown placed on the anode support to adjust the correct height of the filament; to the right another jig is similarly used for the grid



MARCONI-OSRAM POWER VALVE

Fig. 8. This is a powerful amplifying valve, taking an anode potential of 120 to 150 volts

(5) The slope of the anode current-anode voltage characteristic (K_2) is found.

From these quantities we can derive the amplification factor (K) and the internal resistance (R_i) of the valve, since

$$K = \frac{K_1}{K_2}$$

and

$$R = \frac{1}{K_2}$$

It ought to be mentioned that in many modern receiving valves the exhausting is not carried out solely by means of pumping. The clean-up of the gas can be assisted by chemical means. The chemicals used (*e.g.* phosphorus or magnesium) are known as "getters," and recently a procedure has been developed whereby valves are exhausted using a modified bombarding schedule in conjunction with chemical agencies. Valves made in this way can be recognized by their colour or sheen. For example, if phosphorus is used, the glass is amber or straw-coloured, (*e g.* B.T.H. B.4 valve), while if magnesium is used the glass exhibits a silvery, mirror-like appearance (*e.g.* Marconi-Osram D.E.2 or D.E.3, Figs. 8-13).

Before 1920 almost all the valves sold in England for receivers were of the R type and had filaments of tungsten. But in 1920 the General Electric Co. produced commercially the first low-temperature filaments, using thoriated tungsten. (We except here the oxide-coated filaments of low-temperature type made by the Western Electric Co. of America, and which are now also made by the Mullard Valve Co.). The General Electric Co. dull emitter valve reproduced the characteristics of the well-known R valve, but its filament required only ·36 ampere at 1·8 volts (*i.e.* ·65 watt) instead of the 2·8 watts required by the ordinary R type.

A few months later a further step was made, and a valve requiring a filament current of only ·06 ampere at 3 volts (*i.e.* ·18 watt) was designed, but it was not at first put on to the market owing to difficulties of mass production. Ultimately, however, the difficulties were overcome, and these valves were sold to the public. For these low-temperature valves a very

MARCONI-OSRAM R. 5V VALVE

Fig. 9. This type is one of proved efficiency that has a reputation for good results

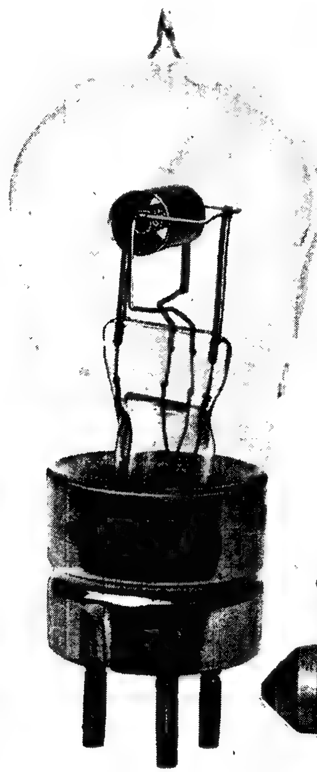
high vacuum is essential for the maintenance of low-temperature emission. Now, the action of magnesium as a "getter" is even more efficient than phosphorus, so the former is used in the manufacture of nearly all dull emitter valves. The magnesium is introduced in the form of a wire or ribbon heated at a definite stage in the bombarding process, and is finally deposited on the bulb walls.

Nowadays the tendency is all towards low-temperature emitters for reception purposes, and it is safe to say that the old R type, which certainly has played its part in wireless history, is obsolescent.

We now proceed to give an account of receiving valves made in England by standard makers. This is most conveniently done in the form of a table.

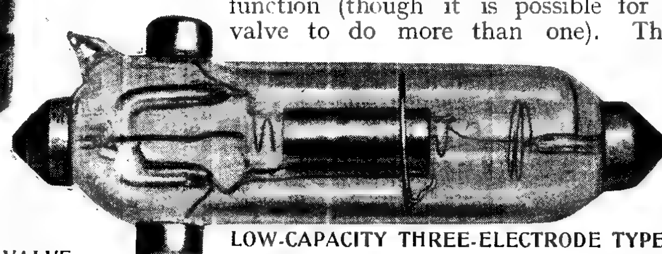
From the table (page 2191) it will be seen that there is a wide range of values from which we can choose for use in a valve receiver. Before giving further details as to the suitability of various types of valves for various functions in a valve receiver, it is necessary for us to consider in somewhat greater detail what these functions are and how far we can assist the valve to perform its functions by the use of suitable elements in our circuit design.

For simplicity we shall consider that each valve performs mainly only one function (though it is possible for a valve to do more than one). The



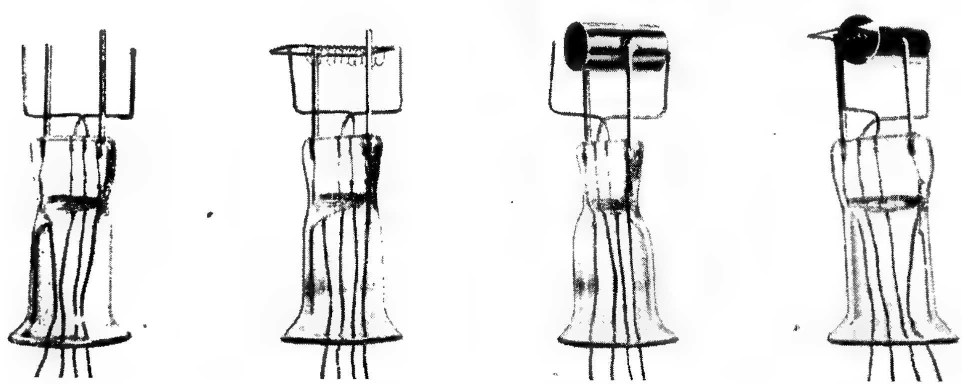
MARCONI-OSRAM D.E.R. VALVE

Fig. 10. This type, an oscillating, rectifying and amplifying valve, is suitable for replacing the bright emitter R valve



LOW-CAPACITY THREE-ELECTRODE TYPE

Fig. 11. In this valve the electrodes are painted in different colours to distinguish them. This valve is also a useful low-power high-frequency generator in local oscillators



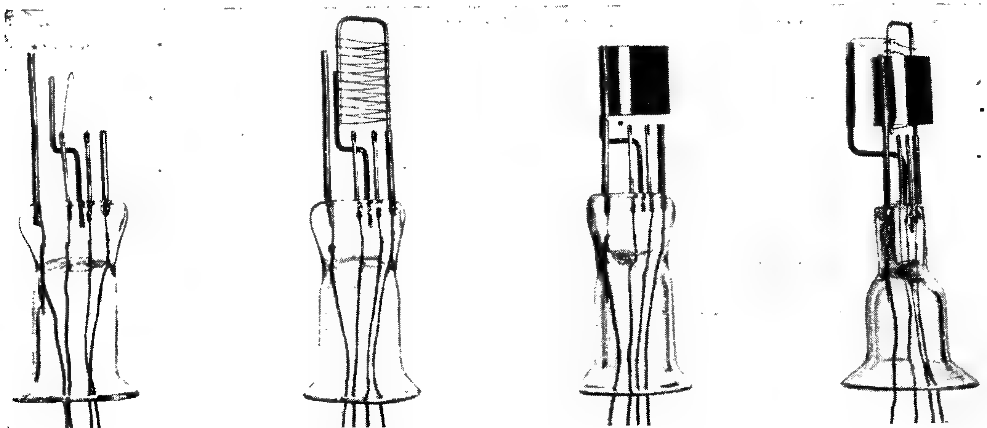
INTERNAL CONSTRUCTION OF THE MARCONI-OSRAM D.E.R. VALVE

Fig. 12. On the left are the supporting pillars of the electrodes. Next are the grid and its oblong support attached to the rear pillar. The third illustration shows the anode fixed to the front support, while the last shows the complete interior structure

RECEIVING VALVES: THEIR CHARACTERISTICS AND USES

This table, prepared by Dr. Appleton as a result of experimental determinations carried out in his laboratory, covers 16 of the valves in general use, and is of considerable value to the experimenter in determining the choice of a valve to meet general or special requirements

Maker	Type	Filament		Electron Emission	Anode Volts	Amplification Factor	Anode Resistance	Remarks
		Volts	Amps.					
Marconi-Osram Co.	R.	4	·70	6 m.a.	60–80	9	40,000 ω.	General purpose valves. Require accumulator 4–6 volts.
	R.Z.	5	·75	6 m.a.	40–60	9	40,000 ω.	
	D.E.1	1·8	·36	5 m.a.	30–45	9	40,000 ω.	General purpose valves of dull-emitter type. Require only one-cell accumulator.
	D.E.2	1·8	·24	5 m.a.	30–45	9	40,000 ω.	
	D.E.3	3·0	·06	6 m.a	25–45	6	22,000 ω.	Suitable for detector, amplifier, and for loud speaker. Requires 4 volt accumulator with resistance, or can be run from dry cells.
	L.S.3	4	·65	6 m.a.	100	5	12,000 ω.	A valve for medium-size loud speakers.
	L.S.5	5	·8	50 m.a.	150	5	6,500 ω.	Suitable for use with large loud speakers, and for telephone-repeater work.
B.T.H. Co.	R	4	·63	—	45–60	—	—	Tungsten filament. Requires two-cell accumulator.
	B.4	6	·25	40 m.a.	40-100	6	7,000 ω.	Suitable for detector with 40 anode volts. For amplifier or loud-speaker work use 60-100 anode volts with negative grid bias of 3–5 volts. Dull emitter filament.
	B.5	3	·06	—	40-80	6	15,000–18,000 ω.	Dull emitter filament. Can be run from dry cells.
Cossor Valve Co.	P.1	4	·72 to ·75	Exceeds 3·6 m.a.	30	6·6	18,000–20,000 ω.	Used as detector or L.F. amplifier.
	P.2	4	·72 to ·75	Exceeds 3·6 m.a.	60–80	12	50,000-60,000 ω.	Specially designed for high-frequency amplification.
Edison-Swan Co.	R.	4	·75	—	50-100	8	25,000 ω.	General purpose valves. Require two-cell accumulators.
	A.R.	4	·65	—	30–80	5·5	22,000 ω.	
	A.R.D.E.	1·8	·30	—	20–50	10	25,000 ω.	Requires only one-cell accumulator. Dull emitter.
	A.R. ·06	2·5–3	·06 to ·07	—	20–50	—	—	Can be run from dry cells. Dull emitter filament.



HOW THE MARCONI-OSRAM R5V VALVE IS CONSTRUCTED

Fig. 13. This type is of somewhat similar construction to the L.S.5 valve. The filament, although shorter, is supported in the same way. The anode, as shown in the third illustration, has a single support, which feature is also shared by the grid

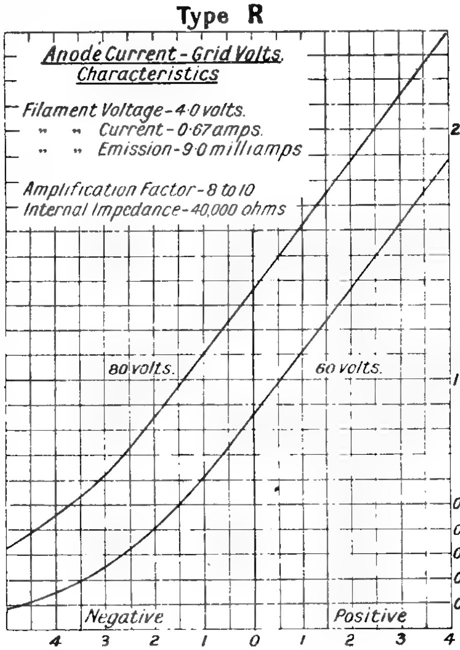
three functions which valves may perform in a receiver are those of:

(1) High-frequency amplifier
(2) Rectifier
and (3) Low-frequency amplifier.

Thus a typical receiver is one of three valves in which the three successive valves perform functions in the order specified. We now proceed to consider these functions in greater detail.

(1) High-frequency Amplification. The essential connexions of the high-frequency valves in three methods of high-frequency amplification are shown in Fig. 19. In each case the aerial circuit is connected to the grid and the filament of the valve responsible for the high-frequency amplification. In each case also a variometer is shown for tuning the aerial circuit. As the high-frequency valve is a potential-

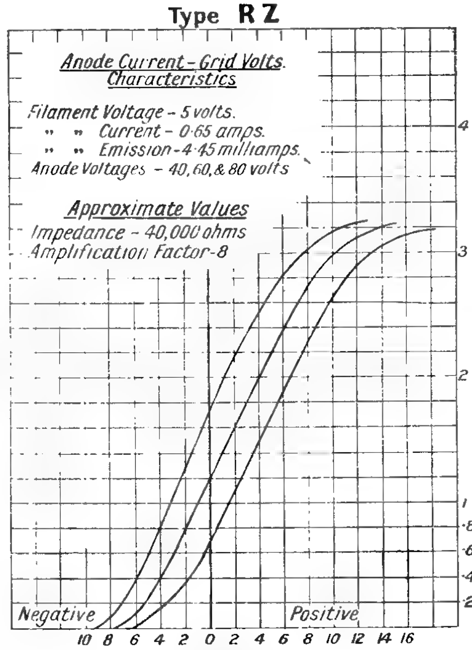
Type R



R TYPE MARCONI-OSRAM VALVE

Fig. 14. Characteristic curve of the R valve, showing the effects of 60 and 80 volts applied to the anode

Type RZ



CHARACTERISTICS OF THE RZ VALVE

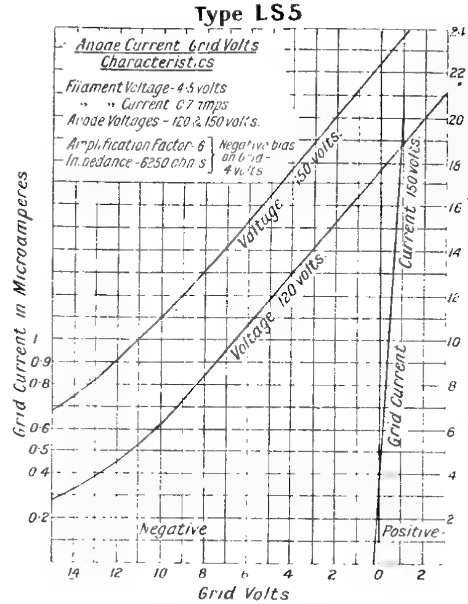
Fig. 15. The curves shown here are for anode voltages of 40, 60 and 80 and a filament voltage of 5

operated device, it is advisable to make the capacity of the circuit as small as possible, so that if a variometer is used no further tuning capacity is required. For example, the variometer made by the General Radio Co. has an inductance range of 100 to 1,230 microhenries, giving a range of 300 to 1,000 metres on a P.M.G. aerial.

In the tuned anode method (Fig. 19 *a*) the oscillatory circuit is tuned in the same way. The connexion from the first high-frequency amplifying valve to the second is made via the grid condenser and the anode battery. This method is very selective and satisfactory in every way. In the method (Fig. 19 *b*) using a high-frequency transformer, air-core coils are normally used. A given pair of coils is usually only efficient as a transformer over a short range of wave-lengths, but it is possible to design a transformer with a tapping switch having a greater range.

In the anode reactance method (Fig. 19 *c*) an air-core inductance is included in the anode circuit, and the potential changes across it are transferred to the grid and filament of the next valve stage via the grid condenser and the high-tension battery. For convenience a tapped coil may be used. Thus the H.F. reactance made by Radio Instruments, Ltd., is suitable for

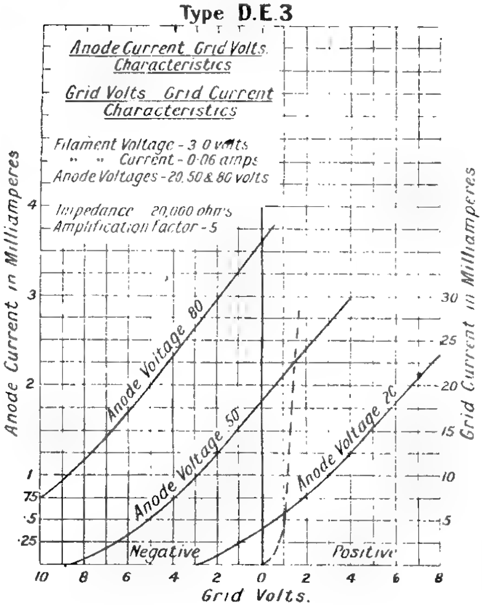
Type LS5



L.S.5 VALVE CURVES

Fig. 17. Characteristics of this loud-speaker valve. Anode voltages should be of the order of 120–150 for the best results, with a generous grid-bias voltage

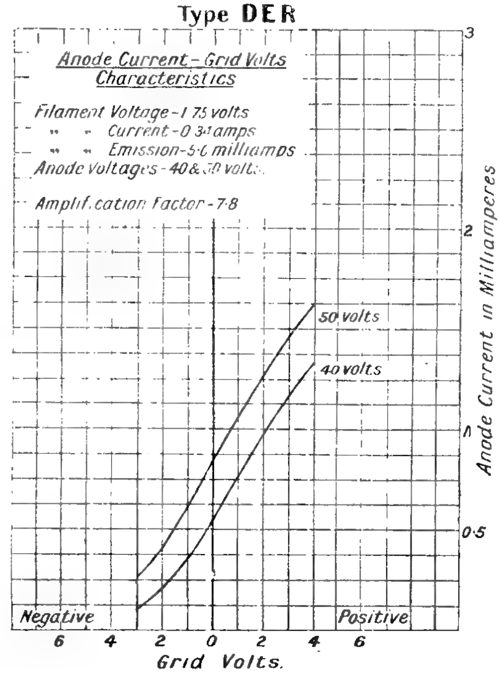
Type D.E.3



CHARACTERISTICS OF THE D.E.3 VALVE

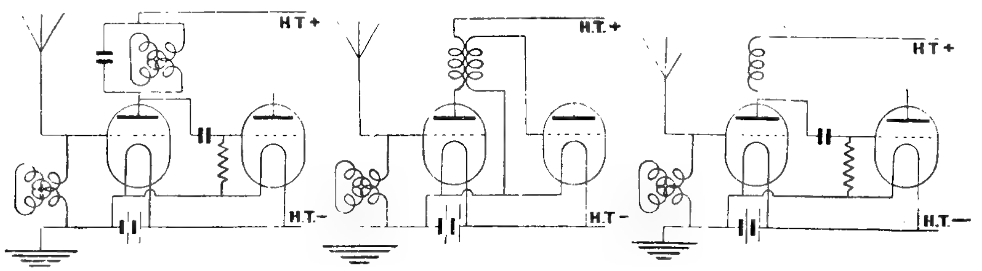
Fig. 16. Curves of the D.E.3 dull emitter, requiring only 3 volts and ·06 ampere in the filament and 25–45 volts on the anode

Type DER



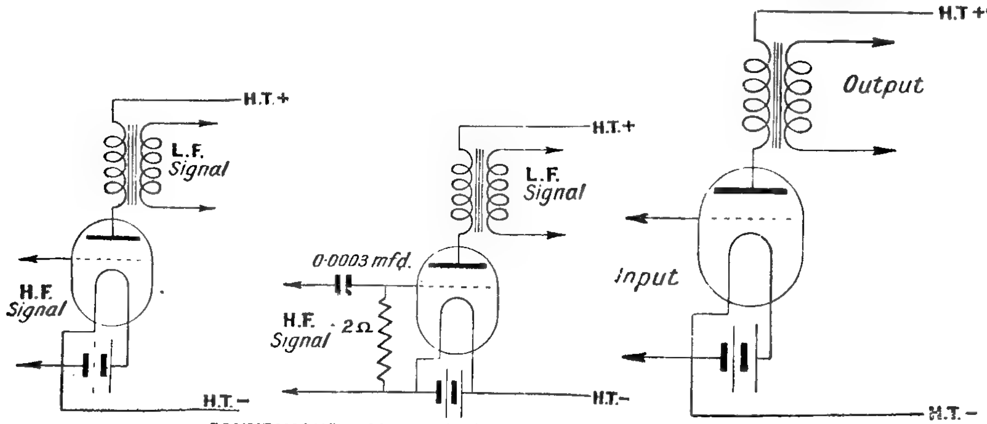
D.E.R VALVE CHARACTERISTICS

Fig. 18. Curves of the D.E.R type, which requires only a one-cell accumulator and a H.T. battery of 40–50 volts



VALVE CONNEXIONS IN HIGH-FREQUENCY AMPLIFICATION

Fig. 19 *a* (left). Tuned anode method of H.F. amplification. *b* (centre). Transformer coupling H.F. amplification. *c* (right). Anode reactance method of H.F. amplification



CONNEXIONS FOR DETECTING AND L.F. AMPLIFYING

Fig. 20. *a* (left). In this circuit the valve is used for reception and detection. *b* (centre). Here the valve receives, detects and rectifies. *c* (right). The valve and L.F. transformer method of reception

use in this way over a range of 200 to 20,000 metres.

(2) Rectification. There are two standard methods of rectification: (*a*) anode rectification; (*b*) cumulative grid rectification. The essential connexions of detector valves for both methods are shown in Fig. 20. In both cases the high-frequency signal to be amplified is applied to the grid and filament, while the resulting low-frequency signal is withdrawn from the anode circuit. Anode rectification (Fig. 20 *a*) depends on the non-uniform relation between the anode current and grid potential, and in choosing a valve for this function it is essential that the characteristic for normal operating anode voltage should be curved.

Cumulative grid rectification (Fig. 20 *b*), on the other hand, depends on the non-uniform relation between grid current and grid potential. Thus in choosing a valve for this purpose it is essential that the grid characteristic for the working grid and anode voltages should be curved. The grid current should also be of suitable magnitude.

(3) Low-frequency Amplification. The most efficient low-frequency amplifying circuit is the combination of a valve and a low-frequency transformer (*see* Fig. 20 *c*). The transformers used are of the step-up type. Examples of standard transformers with winding ratios are:

Radio Instruments inter-valve audio-frequency transformer ..	4 : 1
Igranic inter-valve transformer, shrouded type	5 : 1
Formo inter-valve transformer ..	5 : 1

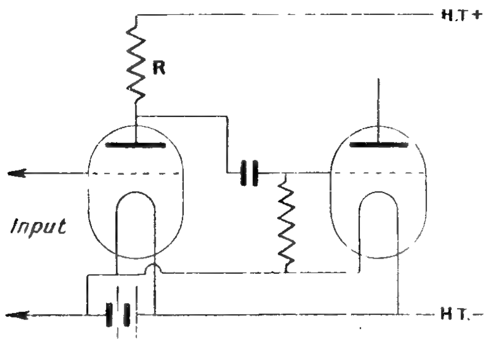
With these transformers and a valve (R type) it is possible to obtain a low-frequency amplification of the order of 20, which is actually higher than the amplification factor of the valve. This amplification is not, however, usually maintained over a very large range of frequencies, so that for the amplification of speech and music the resistance-capacity method of amplification (Fig. 21) is sometimes used.

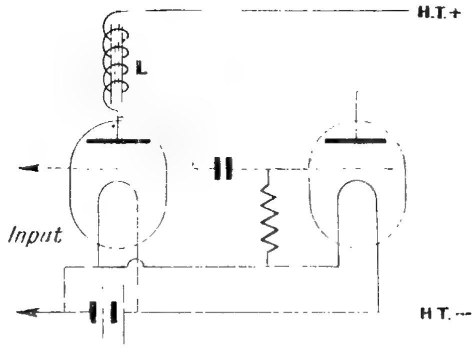
The amplification obtained by this method can never be greater than the value of the amplification factor of the valve, and is usually not more than 6 if R

type valves are used. Moreover, a high anode potential has to be used owing to the drop of potential across the high resistance R. The latter difficulty is to some extent obviated by using a choke inductance, L, of small ohmic resistance in place of the high resistance R (Fig. 22). But even in this case the amplification can never reach a value as high as that of the valve amplification factor, whereas, as mentioned above, the amplification factor can be exceeded if a step up transformer is used.

We now consider the factors influencing our choice of valve in any given case. The main consideration is usually found to be the convenience the experimenter has for supplying filament-heating current. If a 6 volt accumulator is available, and there is no difficulty about charging, valves of the R and RZ type may be recommended because of their cheapness. But in most cases this is not so, and the choice has to be made between the two types of dull emitter valves, of which the D.E.2 and D.E.3 valves may be said to be typical.

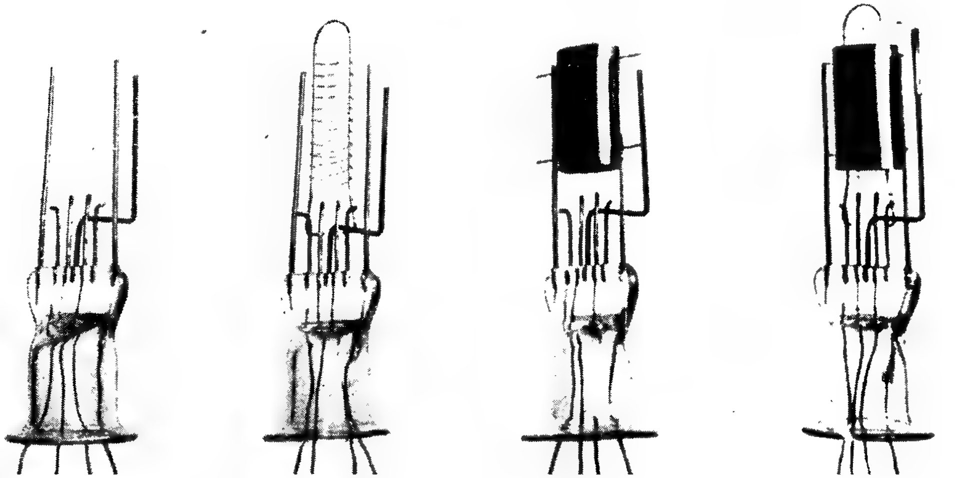
An accumulator is necessary if the former is used, but only ·24 ampere per valve is taken from it, so that with a good accumulator of large capacity the charging need not be a very frequent matter. On the other hand, when the charging of accumulators is quite out of the question, as in country districts, valves of the D.E.3,





LOW-FREQUENCY AMPLIFICATION BY TWO METHODS

Fig. 21 (left). The valves here used obtain amplification by the resistance coupled method. Fig. 22 (right). Amplification is obtained here by the choke inductance method



CONSTRUCTIONAL DETAILS OF THE L.S.5 VALVE

Fig. 23. Shown in the illustration to the left, the filament is supported as indicated in the right photograph by a rod with a spring-ended hook. The second illustration shows the grid construction, and the third the method employed for attaching the oval anode. The completed electrodes are seen on the right

B.5, and A.R. ·06 types may be run on dry cells, as a current of only 60 milliamperes is required. All the valves mentioned above are of the general purpose type, and will act efficiently as high-frequency amplifier, detector or low-frequency amplifier.

For loud-speaker work a valve with a low internal resistance and high emission is most suitable (*e.g.* L.S.5 or B.4). The low internal resistance is usually provided at the expense of the amplification factor, which is low in loud-speaker valves. For high-frequency amplification a higher amplification factor is desirable.

The dull emitter valves mentioned above have a long life so far as filament burn-out is concerned. Useful life is therefore determined by the number of hours for which the initial emission is maintained, and is usually of the order of 1,000 hours.

Recently, valves with coated filaments have been made in England by the Mullard Radio Valve Co. and the Western Electric Co. The power for heating the filament is, for a given electron emission, very much less than that of the pure tungsten filament, and nearly as small as that of the thoriated tungsten filament. The Weco valve has a coated filament, and takes ·25 ampere at ·8 to 1·1 volt for normal operation. Its life is found to be several times that of a pure tungsten filament, and to exceed that of the thoriated tungsten dull emitter filament.

A typical power-amplifying valve is the Marconi-Osram type L.S.5, illustrated in Fig. 23. This valve is a comparatively recent development in power amplifiers, for it is a dull emitter. The filament consumes approximately ·8 ampere, at 4·5 volts, while the anode requires a potential of from 120 to 150 volts.

Reference to the illustration will show that the anode is oval in section, and that it is supported on either side by a very stout wire pillar. The grid, which is also oval, and which closely follows the interior of the anode, is supported on an inverted U-shaped framework of heavy wire. A double filament of an inverted U shape is fitted, the top of which is supported from a hook attached to another pillar situated at the rear of the anode.

The contacts fitted to this valve are worthy of note. It will be seen that they are not of the usual split wire type, but are made in two parts. There is a wire pillar of rather smaller diameter than usual, surrounded by a stamped metal thimble forced upon the central wire. It has been found that this construction eliminates the tendency of repeated removal and replacement of the valve in its socket to reduce the efficiency of the contact between the hollow socket and the valve pin.

VALVES FOR WIRELESS TRANSMISSION

By Professor W. H. Eccles, F.R.S.

During recent years the developments in the broadcasting of wireless transmissions have been phenomenally rapid: and no component has more quickly evolved to assist this advance than the three-electrode transmitting valve. Dr. Eccles contributes an excellent study of its principles and its practice in working. See also Broadcasting; Transmission; Valves for Reception

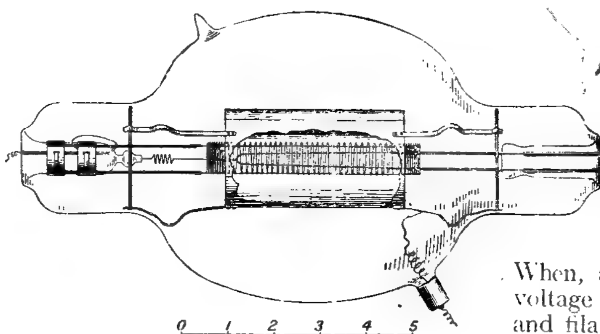
The rapid development of wireless telephony which has taken place during the past ten years has been made possible by the application of the three-electrode thermionic valve to the generation of electrical oscillations.

As soon as it was proved that oscillations so generated gave excellent wireless telephony, great attention was directed to the development of the three-electrode valve, and very soon the valve was being made of a size and quality that fitted it for Morse transmission over hundreds of miles as well as for telephony over tens of miles. As early as 1915 the American wireless engineers showed, however, that they had greater ambitions for telephony than merely to use it for short-distance work; for in that year they succeeded by a special effort in transmitting speech across the Atlantic from Washington to Paris by means of a battery of 300 thermionic tubes operating in parallel. These tubes were of about 25 watts output each, and were then the largest made. Since that date the size of the three-electrode valves has been gradually increased, until to-day they have been built about four thousand times as powerful.

The valves used in transmitting stations are of two kinds, those with two electrodes and those with three electrodes. In either case one of the electrodes, called the cathode, is heated in order that it may emit electrons; the electrons are attracted

across the evacuated bulb from the cathode to the anode when the latter is raised to a high voltage. When they reach the anode they enter its substance and flow along the metal conductors leading to the outside, thus forming an ordinary electric current. The circuit is completed outside the valve by connexions of various kinds, including the source of high voltage, and thus the electrons enter the cathode again and constitute a negative current circulating continuously so long as the cathode is hot and the high voltage is applied to the anode.

The most convenient way of providing a hot cathode in an evacuated bulb is to make it in the form of a filament which is capable of being warmed by the passage of an auxiliary current through it. Another way is to make it in the form of a metal tube inside the bulb and then heat this tube by an incandesced filament inside it or by the process of electronic bombardment.



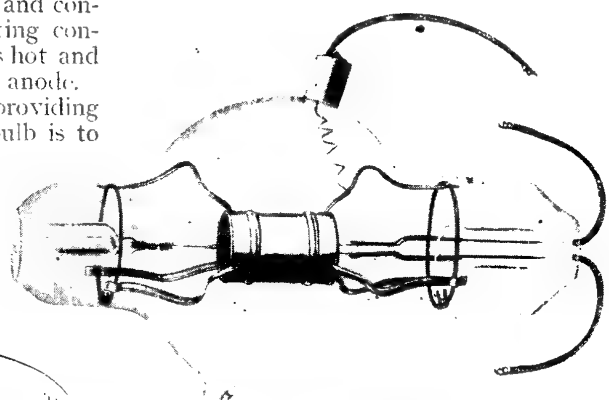
TRANSMITTING VALVE TYPE T.4.A

Fig. 2. This diagram illustrates an Admiralty type of glass valve for transmission. The sizes of its different components may be judged from the scale

Courtesy "Journal of the Institution of Electrical Engineers"

In transmitting valves, as in receiving valves, the most useful conductor for the filament is tungsten, which can be heated to very high temperatures without undue evaporation. At 2,000° absolute, the emission is about 5 milliamperes per square centimetre of tungsten surface, at 2,500° it is about 1 ampere per square centimetre, and at 3,000° it is more than 30 amperes per square centimetre. The rate of emission can be increased by introducing thoria into the filament during the process of manufacture. Such a filament emits at 1,400° the same electron current as would be emitted at 2,000° by pure tungsten.

A two-electrode thermionic valve may be called a diode valve for short, or a Fleming valve. The anode may in general be of any shape. An obviously convenient form of anode is a flat plate fixed parallel to the filament. Another obvious form is a cylinder surrounding the filament. Both forms were used by Fleming, and before him by experimenters on electrons.



MARCONI-OSRAM 100 WATT POWER VALVE

Fig. 1. In this valve the circular anode is supported by metal tripods. The filament is kept tight by a helical spring fixed in the glass at the top end

When, as in large power valves, a high voltage is to be applied between anode and filament, the cylindrical form is best for withstanding the strong mechanical attraction that may arise between two conductors at very different potentials.

In fact, if the filament is a straight one and it is fixed accurately along the axis of the surrounding cylindrical anode, there is no attraction upon it at all, and even if it departs slightly from the ideal centre line the attraction is relatively small. The attraction can also be made very small when the anode is of plate form by making it of two plates, connected together electrically, one on each side of the filament. For medium power valves the plate form is therefore sometimes adopted, but for large power valves the cylindrical construction is almost necessary.

In most diodes the anode is situated within a glass or similar bulb, and is held in position round the filament by means of rigid supports resting on the glass. The variations of design are innumerable. One example is seen in Fig. 1, which shows a 100 watt power valve of Marconi-Osram

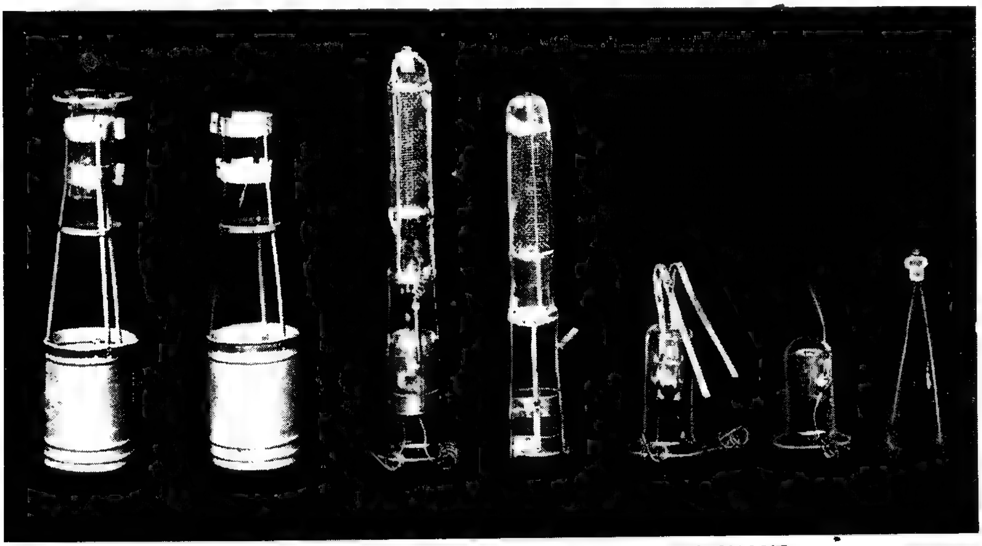
design. The cylindrical anode is here supported both above and below by metal tripods, which bear on the narrowed parts of the bulb. The lead from the anode is taken through a seal in the wide part of the bulb, in order to obtain between anode and cathode a long leakage path over the glass and thus secure excellent insulation between these conductors.

It will be noted that the filament is a hairpin filament kept taut by a helical spring anchored in the glass and attached to the bight. In mounting the electrodes inside the bulb the glass-blower must adjust the tension of this spring, and therefore the tension of the filament, by pulling out or pushing in the glass part while it is being heated in the blow-pipe flame. The Mullard Company employ a small metal index which is also anchored in the glass, and which lies alongside the spring to serve as a gauge for helping the glass-blower to give a predetermined tension to the filament.

In the operation of these power rectifiers the anodes become very hot and are often worked at a red heat. The heat is produced by the impact of the electrons, which, after emission from the filament, attain high velocity and bombard the anode violently. For example, if the anode is 1,000 volts positive relative to the filament, the electrons will be moving at a speed of 11,000 miles per second when they strike, and the kinetic energy they possess is dissipated by heating the anode. This waste of energy during the use of a rectifying tube is inevitable until someone invents a way of landing the electrons on the anode without concussion.

This heating of the anode affects considerably the design and the manufacture of large valves. In the first place, the metal must be chosen to withstand easily the effects of high temperature. The metal ordinarily used in receiving valves is nickel; but in power valves the most suitable metal is molybdenum. A few years ago molybdenum anodes were made by weaving molybdenum tape into a basket-like cylinder, but nowadays they are simply rolled sheet metal. It is found that a molybdenum anode can dissipate four times as much heat as a nickel anode; so higher voltages can be employed with a molybdenum anode of the same size as the nickel anode, and there is less danger of damage by accidental overheating.

In the second place, in using power valves, provision must be made for getting rid of the heat. In a bank of rectifiers for a big transmitting station about 20 or 30 kilowatts must be disposed of. A certain amount of the heat is radiated to a distance; but if the bulb is of glass this



VARIOUS PARTS OF THE M.T.6 TRANSMITTING VALVE

Fig. 3. Here are portrayed the different stages of the construction of the M.T.6 valve. From left to right are shown: anode mounted; anode unmounted; grid mounted; grid unmounted; filament mounting and seals

Courtesy Marconi's Wireless Telegraph Co., Ltd.

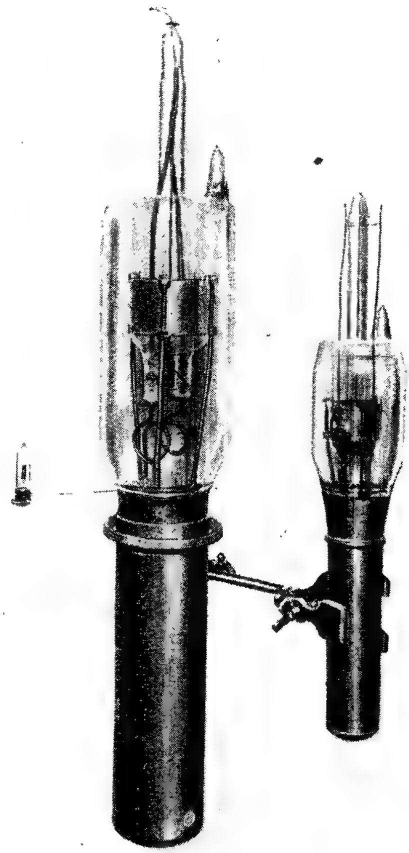


Fig. 4. An illustration of the Western Electric Co.'s latest type of water-cooled transmitting valve

Courtesy "Electrical Communication"

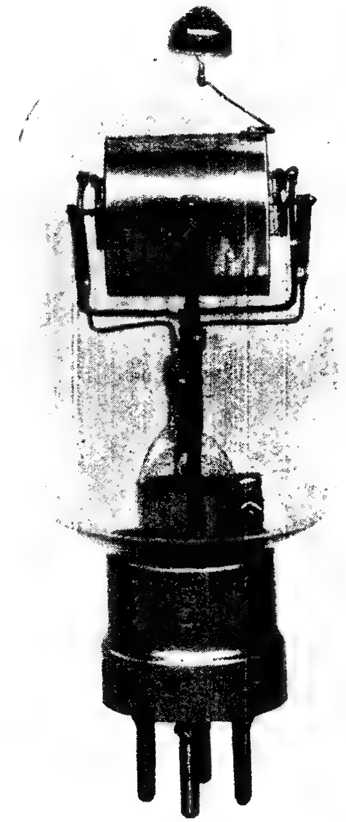


Fig 5. M.T.5 transmitting valve, which dissipates 25 watts at the anode, suitable for voltages up to 1500

Courtesy Marconi's Wireless Telegraph Co., Ltd.

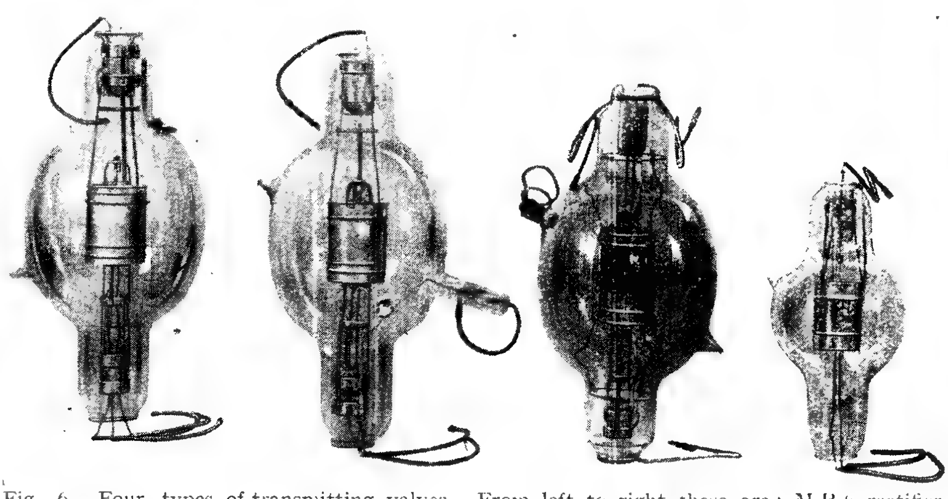
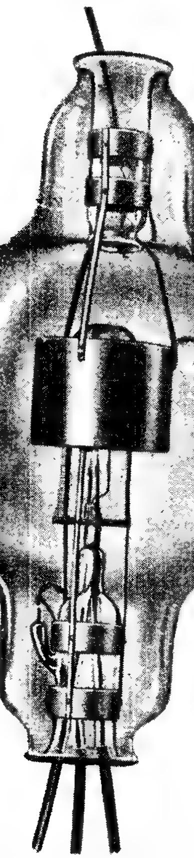


Fig. 6. Four types of transmitting valves. From left to right these are: M.R.6 rectifier; M.T.6; T.450 high-power valve; and M.R.4 medium power rectifier

Courtesy Marconi's Wireless Telegraph Co., Ltd.

MODERN TYPES OF HIGH-POWER TRANSMITTING VALVES



M.T.4 VALVE FOR TRANSMISSION

Fig. 7. Tests of this valve have shown that it will dissipate 200 watts at the anode and is suitable for voltages from 7,500 to 10,000

Courtesy Marconi's Wireless Telegraph Co., Ltd.

absorbs some of the radiation and gets very hot. It then has to be cooled by the use of an air-blast furnished by a constantly running blowing engine or compressor.

In the third place, the manufacture of power valves is much more difficult than that of receiving valves. The fact that the anode becomes very hot in use compels the manufacturer to get rid of absorbed gas more thoroughly than is necessary in the manufacture of receiving valves. The process of exhaustion is pursued to extreme lengths, and the pumps are kept running some hours while the anode is bombarded by electrons from the filament in the same way as it will be bombarded in use.

Indeed, the bombardment during manufacture should be carried on at a higher voltage—that is to say, with even more vigour—than will be experienced later. At the same time the glass must be heated by an external agency to a higher temperature than it is likely to experience in action, and this is best done in a furnace which can itself be partially evacuated to remove the pressure of the atmosphere from the bulb while it is heated almost until the glass softens.

While applying to the anode a voltage higher than will normally be applied to the finished article, the manufacturer meets a rather curious difficulty which causes a number of failures during the bombarding process. The high voltage on the anode accelerates the electrons from all parts of the filament and attracts most of them to itself; but some of the electrons from near the ends of the filament may, after getting up a high speed, shoot past the anode and strike the glass. When this happens to a sufficient extent the bombarded area of the glass may get so hot that the atmospheric pressure blows a hole in it and ruins the valve. This accident may be prevented by making the cylinder long enough to cover the ends of the filament.

The object of the elaborate manufacturing process indicated above is the complete removal of gas, whether free, or occluded in metal, or absorbed on glass. The free gas is easily removed by modern pumps, but gas in the solid parts is less easy to eliminate, and gradually comes out in working. This free gas is easily ionized by the high-speed electrons—that is to say, the gas molecules are broken into positive ions and negative electrons. The negative electrons join the main electron torrent and rush towards the anode. The positive ions are repelled from the anode, gain speed, and rush at the filament.

Doubtless most of the ions, in passing through the dense cloud of electrons just leaving the filament, are neutralized; but their momentum carries them right on to the filament, and they may heat portions of it so greatly as to cause actual evaporation of the metal. This is the beginning of the end of the filament. In the early days the endeavour to use high voltages in order to handle large powers resulted in rapid destruction because the art of evacuation was not systematized.

The life of a filament might then be one or two hundred hours. To-day many high-voltage valves live two or three thousand hours. It may indeed be said

that the life of a properly exhausted valve is a matter of filament thickness, and that the end comes because of unevenness in gauge or texture. The initially thin parts of a filament tend to become thinner still because the heat developed by the heating current is greater at the thin parts, and the evaporation of metal in the emission of electrons is therefore greater there. Obviously, thick filaments can be made of more uniform gauge and quality than thin ones, and on this account their life should be longer.

A thick filament requires a greater heating current than a thin one, and, other things being equal, costs more per hour in working. The designer or purchaser has therefore to balance shortness of life against running costs when deciding upon the thickness of filament he will specify in ordering a quantity of power valves.

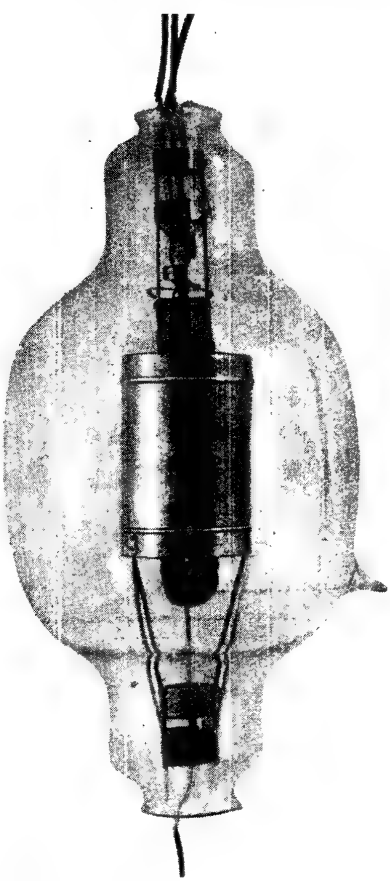
Practically all that has been written above about the manufacture of valves with two electrodes applies also to valves with three electrodes, which may be called triodes. The triode differs from the diode only by having a grid interposed between the filament and the anode. The theory of the grid is the same in transmitting as in receiving valves. Because the grid is nearer the filament than the anode is, a small voltage applied to the grid is equivalent to a large voltage applied to the anode, and therefore small changes of grid voltage produce relatively large changes of anode current. The difference between transmitting and receiving triode valves lies solely in their size and design in detail.

The chief points in filament and anode design have already been explained for diode valves; the only additional feature in triode valves arises in the design of the grid, which must be supported to withstand great electrostatic pulls and must be thick enough to endure considerable bombardment.

During the war triode valves were made of gradually increasing size, until at last glass valves capable of dealing with half a kilowatt of input energy were standardized. The British navy meanwhile developed silica valves of even higher power. Silica has many advantages over glass; it allows of the anodes being worked at temperatures so high that glass would soften and collapse, and it is more translucent to heat rays, and therefore keeps cooler than glass.

The metal parts of both the glass and the silica valves are practically the same, but in silica valves the anode is made smaller than it could be made in glass valves of equal rating. A dimensioned sketch of an Admiralty glass valve is given in Fig. 2, which is taken from a paper read by Gossling before the Institution of Electrical Engineers. Recently Colonel Morris Airey, of the Admiralty, has exhibited a silica valve capable of dealing with over 50 kilowatts.

The latest development in valves, both diode and triode, consists in cooling the anode by flowing water or oil. Such a valve presents the appearance of a metal cylinder with a flat bottom, surmounted by a bulbous top of glass. The exposed metal cylinder is the anode, the grid and the



M.T.2 TRANSMITTING VALVE

Fig. 8. This high-power transmitting valve dissipates 600 watts at the anode, and is suitable for voltages up to 1200

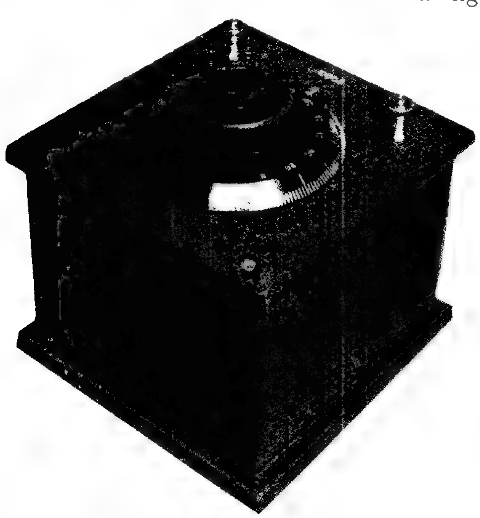
Courtesy Marconi' Wireless Telegraph Co., Ltd.

filament being held in place within it by means of leads and supports sealed into the glass top. The glass top is itself sealed to the metal anode.

The water-cooled valve made by the Western Electric Company is illustrated in Fig. 4. This type of valve is also made by the General Electric Company of America and by Phillips of Holland. Some of these valves have been built of large size. The standard Western Electric valve is capable of dealing with an input of more than 15 kilowatts at 10,000 volts on the anode; but experimental valves have been built by the company to deal with more than 200 kilowatts.

As an example of a modern large valve equipment that at the Radio Corporation's station at Rocky Point, Long Island, may be cited. The valve equipment was supplied by the General Electric Company of America. It consists of a bank of three 50 kilowatt diode rectifiers and a bank of six 20 kilowatt triode oscillation generators. The primary supply of electric energy is 30,000 volts alternating current; this is rectified by the first bank and passed to the triode bank, which converts it to high-frequency current. A current of 350 amperes was maintained in the aerial during a test of sixteen hours.

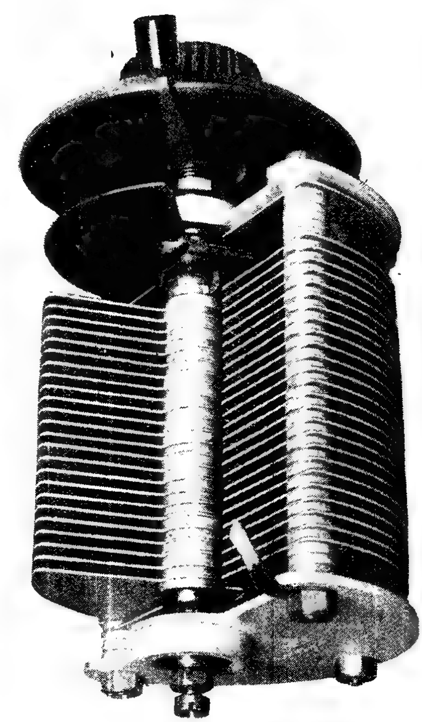
VALVE SOCKET. Name given to a small brass component chiefly employed by the amateur constructor as a means of making up a holder for an ordinary three-electrode valve. *See* Valve Leg.



MOUNTED VANE CONDENSER

Fig. 1. It is best to mount vane condensers in a case as shown to prevent dust or dirt accumulating on the plates and altering the capacity

Courtesy Peto-Scott Co., Ltd.



VERNIER VANE CONDENSER

Fig. 2. In this example a vernier adjustment is fitted for fine tuning. This instrument is of very accurate construction

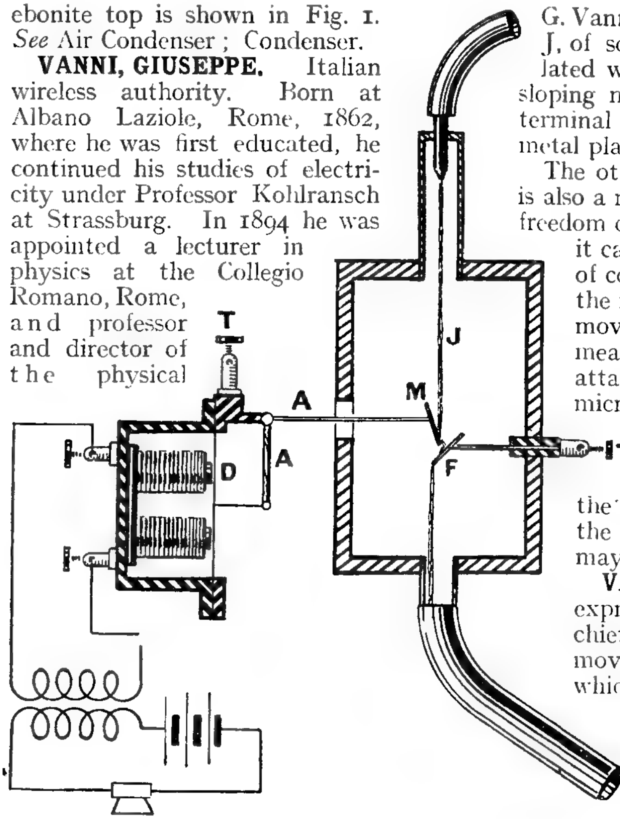
Courtesy Peto Scott Co., Ltd.

VANE CONDENSER. Name applied to many patterns of variable condenser characterized by the use of a number of flat plates. One example is illustrated in Fig. 2, showing a Peto-Scott pattern with a vernier attachment. The condenser is composed of fixed plates arranged parallel to each other and secured to three tie rods, the plates being separated by small washers. The end plates are thicker than the others and act as the supports for the rods and the bearings for the centre spindle. Other and smaller plates are similarly mounted on the spindle, which is free to turn within the fixed plates, under the control of the dial and knob. A separate movable plate acts as a vernier, and is actuated by a small lever and knob. Vernier condensers are also dealt with under the heading Vernier in this Encyclopedia, and under the heading Condenser.

Vane condensers should be kept free from dust and dirt, and the method of mounting them in a small case with an

ebonite top is shown in Fig. 1. *See* Air Condenser ; Condenser.

VANNI, GIUSEPPE. Italian wireless authority. Born at Albano Laziole, Rome, 1862, where he was first educated, he continued his studies of electricity under Professor Kohlransch at Strassburg. In 1894 he was appointed a lecturer in physics at the Collegio Romano, Rome, and professor and director of the physical laboratory of the Military Radio Telegraphic Institute in Rome, 1912. The same year he took part in the International Radiotelegraphic Conference in London, and also in those held in Paris in 1912 and 1913.



VANNI'S LIQUID MICROPHONE

This illustration portrays diagrammatically the liquid microphone of Giuseppe Vanni, and indicates clearly the principles of its action

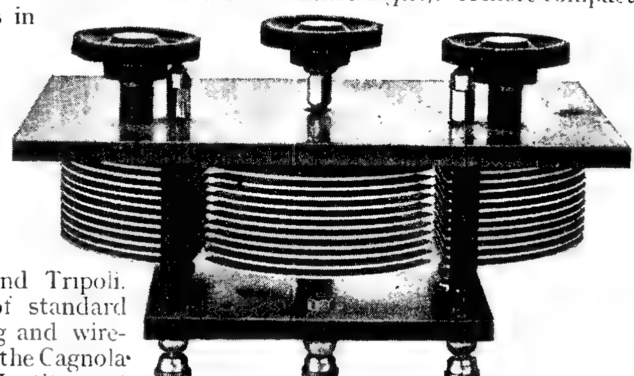
Professor Vanni is one of the most brilliant of the Italian wireless authorities. He is the inventor of an ingenious form of liquid microphone, separately described in this Encyclopedia, with which he carried out telephonic communication between Rome and Tripoli. He has written a number of standard books on electrical engineering and wireless, and in 1914 was awarded the Cagnola Prize of the Royal Lombard Institute of Science and Literature in Milan.

VANNI'S LIQUID MICROPHONE. Type of liquid microphone due to G. Vanni. In the Vanni microphone a jet, J, of some conducting liquid, as acidulated water, is made to impinge on a sloping metal plate, F, which forms one terminal of the microphone. This sloping metal plate is fixed in position.

The other electrode of this microphone is also a metal plate, M, but it has a certain freedom of movement, so that one edge of it can just dip into the thin stream of conducting liquid that flows over the fixed electrode. The play of the moving electrode is controlled by means of a lever mechanism, A, attached to the diaphragm, D, of the microphone. The vibration of the diaphragm causes the moving electrode to dip in and out of the stream of liquid between the two electrodes, and this varies the resistance to any current which may be passing.

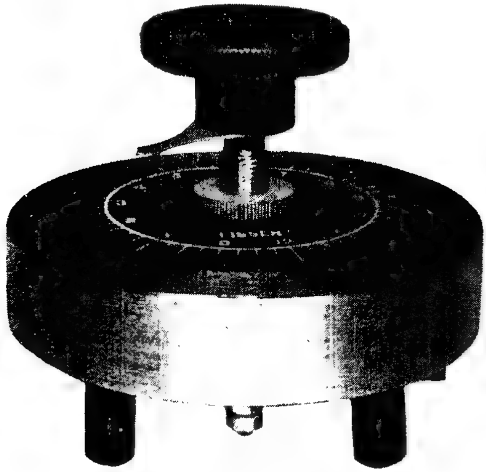
VARIABLE CONDENSER. The expression variable condenser is chiefly applied to instruments of the moving-vane type, a development of which is illustrated in Fig. 1. This is known as the 3 E.V.C. condenser, and has many applications in conjunction with the elimination of interference and for many forms of bridged or balanced circuits. There are three variable elements in this condenser, the outer pair of moving plates and the inner or bridging plate, the plates of which are adjustable separately and relatively to each other.

Other forms of variable condenser are illustrated and described under the headings Air Condenser, Condenser, Tubular and Vernier Condensers (*q.v.*). A more compact



3 E.V.C. TYPE OF CONDENSER

Fig. 1. Here there are three variable condensers in one. This type of instrument is particularly valuable in interference-eliminating circuits



LISSEN VARIABLE CONDENSER

Fig. 2. Compactness is the striking feature of this instrument. In this type mica or some similar dielectric is employed instead of air

Courtesy Lissen, Ltd.

type of variable condenser is illustrated in Fig. 2, and is known as the Lissen. This, and others of other makes, incorporates the principle of two or more adjustable plates separated by a dielectric of mica or other material not air. One plate is usually fixed and the others adjustable, as regards their distance from it, by means of an ebonite knob. Such condensers have the merit of considerable range of capacity while occupying small space. *See* Air Condenser; Condenser; Tubular Condenser.

LISSEN VARIABLE GRID LEAK

Suitable for panel mounting, this component has soldering tags attached for connecting the wires in position

Courtesy Lissen, Ltd.

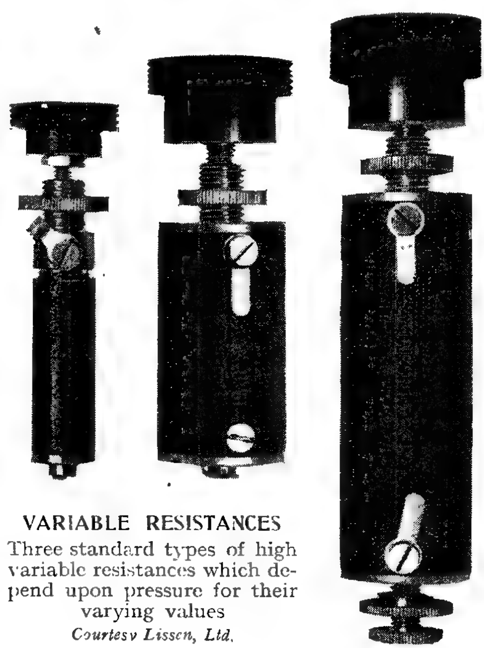
VARIABLE GRID LEAK. Term used to describe all forms of grid leak with ready means for altering their value. One device, known as the Lissen, is shown in the illustration. It has an ebonite case with a centre hole fixing for panel mounting, the alteration of value being obtained by rotation of the ebonite knob. Soldering tags are fitted for the attachment of the connecting wires. *See* Grid Leak.

VARIABLE INDUCTANCE. Term applied to all forms of inductance which are so arranged that the effective value can be altered at will. Among the methods that have been adopted are the sliding type of inductance, and the use of tappings and contact points of studs controlled by an inductance switch. *See* Coil; Inductance; Tapping, etc.

VARIABLE RESISTANCE. Strictly speaking, an expression covering all forms of adjustable resistance. In wireless work the term is more applied to those resistances of high value required in many circuits. There are many patterns, but these illustrated are characteristic, and known as the Lissen. The actual resistance is a compound of high resistivity and is varied by alteration of the pressure exerted by the screwed spindle rotated by the small ebonite knob. *See* Resistance; Rheostat.

VARIO-COUPLER. Name given to a tuning device. A vario-coupler consists of two elements, first a fixed portion which is virtually an inductance coil wound upon a tubular or spherical former, and often known as a stator, and a movable portion known as a rotor. The latter may take the form of a basket coil, spherical rotor ball, or other convenient form. In addition, a vario-coupler may actually consist of two plug-in type coils, suitably connected and tapped. In this Encyclopedia the application and construction of vario-couplers are fully dealt with, *e.g.* under Armstrong and Reflex Sets.

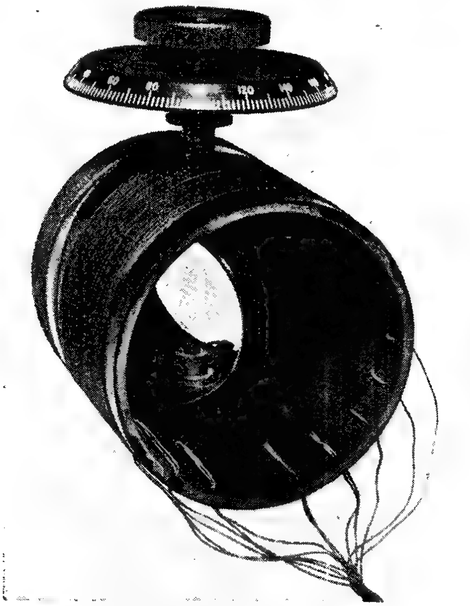
As regards the rotor ball type of



VARIABLE RESISTANCES

Three standard types of high variable resistances which depend upon pressure for their varying values

Courtesy Lissen, Ltd.



GECOPHONE VARIO-COUPLER

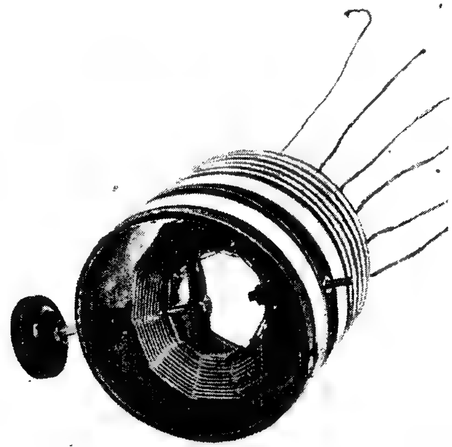
Fig. 1. In this type the rotor is mounted inside a tubular tapped inductance as the stator

Courtesy General Electric Co., Ltd.

instrument, such as that illustrated in Fig. 1, which is known as the Gecophone vario-coupler. this part of the device follows the same methods of construction and winding as that described in the article on rotor (*q.v.*). The Gecophone vario-coupler comprises a tapped stator in the form of an inductance on a tubular former, the rotor being mounted within the tube and controlled with an ebonite knob and dial.

In another pattern, illustrated in Fig. 2, a somewhat similar arrangement of a tapped inductance is used in the primary, while the rotor in this case consists of a lattice-wound basket-type coil mounted on two short spindles in a similar manner to a variometer, the movement of the rotor being controlled by an ebonite knob.

In instruments of this general type the wiring may be carried out in various ways. The tappings in the primary are usually carried to a stud switch controlled by a movable contact arm and connexions made in the usual way to aerial, earth and the detector. The rotor may be wired into the circuit either as a reaction coil or as a coupling coil to a secondary inductance of suitable value, in which case the primary is connected to aerial and earth and one side of the secondary taken to the detector. The vario-coupler is in this sense a

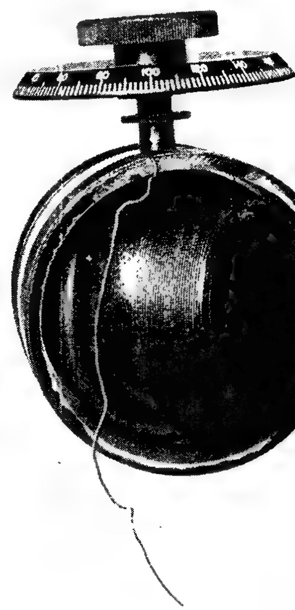


COMMON TYPE OF VARIO-COUPLER

Fig. 2. Here a lattice-wound basket coil is used as a rotor, movement being controlled by the knob

most adaptable instrument for tuning purposes. *See* Coil; Rotor; Stator; Variometer. *See* also under the names of various sets using vario-couplers.

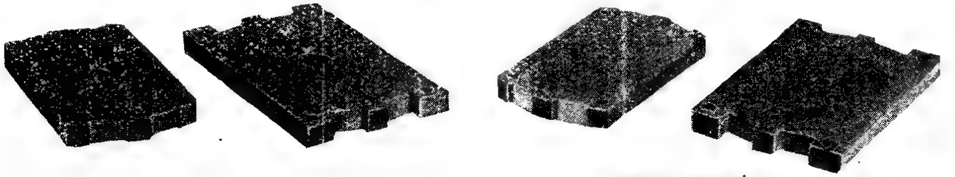
VARIOMETER. A form of variable inductance in which the variation is made without alteration to the amount of conductor in the circuit. In practice, the

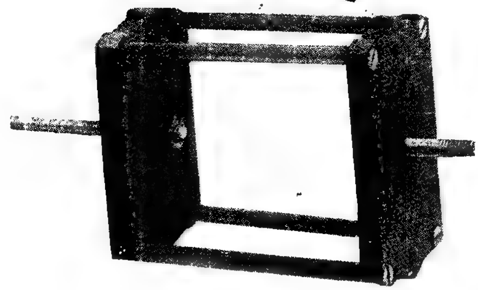


GECOPHONE VARIOMETER

Fig. 1. The rotor here is mounted on two half-spindles projecting through the stator walls

Courtesy General Electric Co., Ltd.

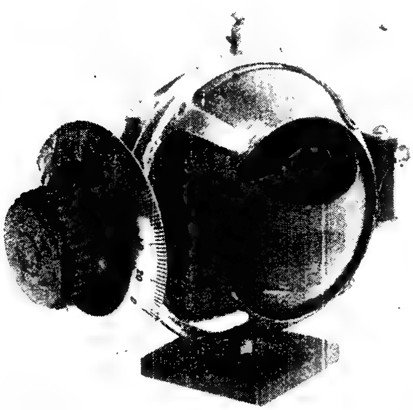




FOR HOME CONSTRUCTION

Fig. 2 (above). Four ebonite plates are cut to shape and drilled to form end supports of the home-made variometer. Fig. 3 (right). End plates of the rotor are now in position and the central spindle fitted

variometer usually comprises either a tubular or spherical exterior member or stator, with a spherical internal member known as the rotor. An example of this type is the Gecophone variometer, illustrated in Fig. 1. The rotor is mounted on two half-spindles which project through bushed holes in the walls of the stator, movement of the rotor being controlled by means of a dial and knob.



G.R.C. VARIOMETER

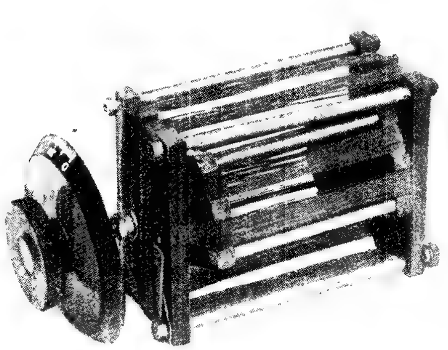
Fig. 4. Both stator and rotor in this example are wound without formers, an insulated outer cage carrying the spindle and ebonite blocks

Courtesy General Radio Co., Ltd.

A variometer is wired so that there are only two ultimate ends to the winding proper. The outer windings commence at one terminal, the requisite number of turns are made outside the stator former, and the end of this wire connected to the commencement of the rotor winding, such connexion being effected by means of bushing and half-spindle and by contact strips. Other methods include the use of flexible wire, contact brushes, and so forth. The end of the rotor winding is similarly connected to the other half-spindle, and this is connected to the second terminal.

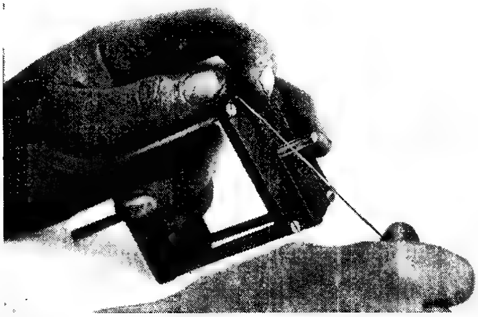
A particularly good example of a variometer suitable for broadcast band of wave-lengths is that illustrated in Fig. 4, as supplied by the General Radio Co., Ltd. This is built up so that only the winding itself is needed to form the major portion of the stator and rotor, the latter having a small ring or flange which acts as a support to the spindle, the stator having an insulated outer cage of metal to carry ebonite blocks and supporting bushes for the rotor spindle.

The small ebonite plate is connected by means of a screw in the end of the stator framework and enables the frame to be fixed under any reasonable conditions. The modes of wiring and making variometers of the spherical type are described in the articles Stator and Rotor (*q.v.*).



HOME-CONSTRUCTED VARIOMETER

Fig. 5. This simple variometer is easily made at home. Two rectangular formers are used in place of the more usual spherical ones



WIRING THE ROTOR

Fig. 6. To hold the wiring of the rotor firmly in place notches are cut in the end plates. Note the positions of the hands

A suitable simple and effective construction for amateur purposes is illustrated in Fig. 5, from which it will be seen that the spherical formation is substituted by the use of two rectangular windings supported by flat ebonite end plates. These are connected together by means of ebonite or brass rods to form two pairs, the smaller being arranged to rotate within the other.

For broadcast purposes, when used in conjunction with the average aerial and a low value series condenser, the variometer plates may measure 4 in. long, 3 in. wide and $1\frac{7}{8}$ in. deep for the stator, and $3\frac{3}{8}$ in. long, $2\frac{3}{4}$ in. wide and $1\frac{1}{2}$ in. deep for the rotor. These ebonite plates are then squared up and radial notches cut in the ends of them, as shown in Fig. 2. Central holes are drilled for the bush and spindles respectively. Other holes are drilled near the corners for the passage of the tie-rods. Two holes should also be drilled and tapped in one of the plates so that the variometer may be screwed to the panel.

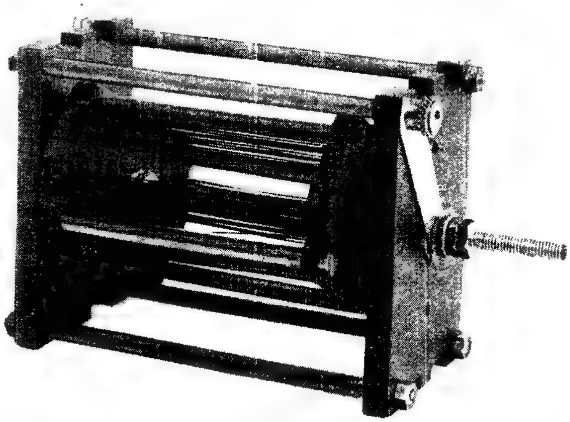
After the plates have been prepared they should be tested by mounting them on a rod and rotating them to see that the radial slots are correctly cut, and that the ends of the pieces for the rotor are also cut to a radius. There should be a gap of about $\frac{1}{8}$ in. between the outside diameter of the rotor plates and the bottom of the radial walls on the fixed or stator plates. The rotor is then assembled, as shown in Fig. 3, by means of four equal-length rods of brass or ebonite about $\frac{3}{16}$ in. in diameter. The ends of these rods are drilled and tapped, and No. 4 B.A. countersunk screws passed through the holes in the rotor end plates and screwed into the rods.

Two short lengths of screwed rod are then fixed in the centre holes and secured with lock nuts in the usual way, to act as spindles.

The next step is the wiring, which may be performed with ordinary No. 20 gauge enamelled copper wire. As many turns as possible should be made, commencing from one of the outside corners of the notches until the notches on one side of the spindle are completed. The wiring is then swept across to the next notch and continued as in Fig. 6.

After the wiring is finished, the two ends should be connected one to each of the spindles by means of lock nuts. The stator plates should then be assembled on the rotor by means of rods, which may be screwed into the holes in the end plates and secured with lock nuts. Two terminal nuts should be fitted on the outside end of the top pair of rods, each of these rods being connected to one of the half spindles of the rotor by means of a copper contact strip, the whole arrangement being clearly illustrated in Fig. 7.

To keep the rotor in place and keep the winding from rubbing against the end plates of the stator, one or two spring washers should be interposed between the two pairs of end plates, and the length of the stator rods being rather longer than those

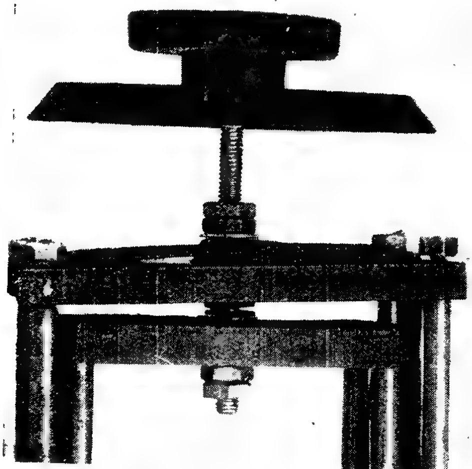


HOW THE ROTOR IS FITTED IN THE STATOR

Fig. 7. Here the variometer is nearing completion, and the rotor is fitted inside the stator. Note the connecting strip between the central spindle and the stator terminal

for the rotor, gives sufficient clearance. These spring washers and other constructional details are shown in Fig. 8.

The stator is wound in a similar manner to the rotor, but it is necessary to interpose a thin strip of insulating material between the winding and the contact strips. The final stage in the wiring, as well as these contact strips, is illustrated in Fig. 9. The stator winding has to be carried out



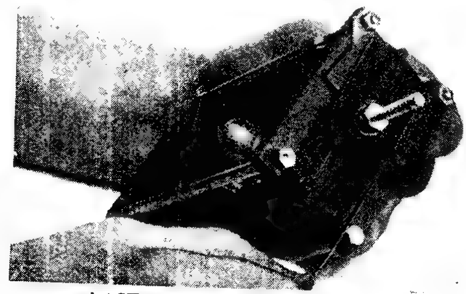
DIAL AND SPINDLE DETAILS

Fig. 8. Spring washers are employed to keep the rotor end plates from jamming against the stator end plates

after the rotor is assembled in its place, as it is otherwise difficult properly to connect the rotor to the spindles. The commencing end of the stator winding should be attached to one of the rods having a terminal on it.

The winding is then continued as in the case of the rotor, and should be in the same direction. The ultimate end of the rotor winding is connected to the other rod of the stator, which is also provided with a terminal. On making a battery test with telephones in the usual way, the circuit should now be completed through the terminal. The current should have an unbroken metallic path from the first terminal, around the stator winding to the second rod, which is connected to the variometer spindle by means of a contact strip, shown in Fig. 7.

The current then passes through this strip, through the rotor half-spindle, thence through the contact strip to the second terminal on the stator. In use, tuning is effected by varying the degree



LAST STAGE IN THE WIRING

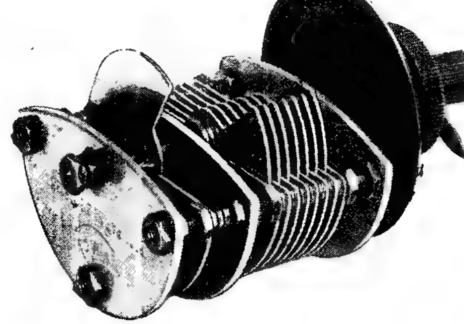
Fig. 9. The final stage of the wiring is shown here. The rotor winding is completed and the last stage of the stator winding is in progress

of coupling between the rotor and stator. Results may only be obtained when the rotor is turned through 180 degrees. This may arise should the winding be arranged in opposite directions. *See* Coil; Inductance.

VARIOMETER WAVE-METER. Form of wave-meter employing a variometer as the variable inductance. The best form of variometer wave-meter is that due to Professor J. S. Townsend and patented by him. This form of wave-meter, by means of a two-way switch, may be used for long or short wave-length ranges. *See* Wave-meter.

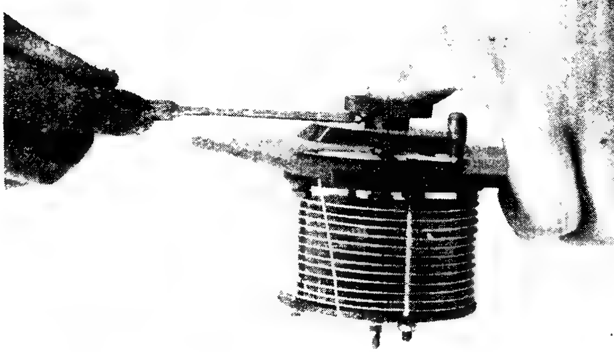
VERNIER CONDENSER. A condenser of low value used in a circuit for fine tuning purposes.

A vernier variable condenser of such construction is illustrated in Fig. 1, and in this three end plates are used, thus providing for adequate support of the vernier spindle, imparting to it an



CONDENSER WITH VERNIER ADJUSTMENT

Fig. 1. Between the lower end plates an additional moving and fixed pair of plates, controlled separately, provide vernier or fine adjustment of capacity



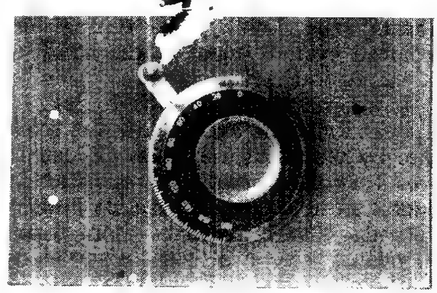
VERNIER CONDENSER DETAIL

Fig. 2 (above). In this form a fixed plate is secured to the panel beneath the dial. Fig. 3 right). Attaching the fixed plate to the panel by means of countersunk screws

independent means of adjustment. Such condensers are usually reliable and robust in use and not easily deranged.

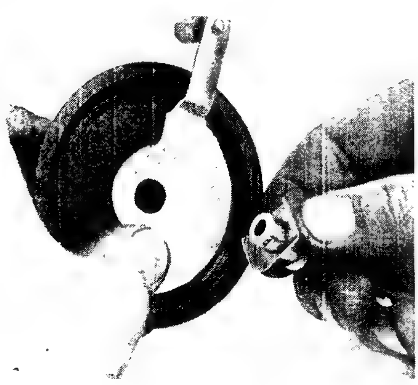
The experimenter will often be called upon to convert an ordinary variable condenser to a vernier condenser. One method by which an extensively used make of variable condenser can be adapted as a vernier is illustrated in Fig. 2. The method consists essentially of attaching a fixed plate to the outside of the panel, attaching to the underside of the dial another metal plate, and altering the dial knob so that the dial only may be rotated while the knob remains stationary.

The first step is to take an ordinary fixed condenser plate and screw it by means of countersunk brass screws to the outside of the panel, as is shown in Fig. 3. The next operation is to part the knob from the dial, if necessary sawing them asunder. A special metal plate is then cut from brass or aluminium and should be similar in general shape to the ordinary moving plates, but should have an outwardly



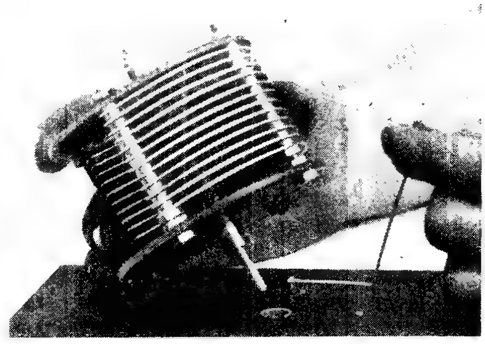
DIAL OF THE CONDENSER

Fig. 4. Plan view of the dial, showing the control knob for the vernier plate of the condenser



SPECIAL ADJUSTING PLATE

Fig. 5. Here the special metal plate is being fixed in position on the dial. This part of the construction calls for careful work



WIRING THE VERNIER CONDENSER

Fig. 6. In wiring the condenser one lead is brought through the panel to the fixed plate beneath the dial

projecting arm. The shape of this arm, as well as the small ebonite knob which is connected to it, is shown in Fig. 5.

The dial should be provided with a small bush and spring to keep it in its place, this detail being also visible in Fig. 5, where it is shown held between the operator's finger and thumb. The whole purpose of this little spring and bush is to provide a bearing for the dial to rotate upon. A plan view of the dial, knob and adjustable handle is shown in Fig. 4.

The wiring necessary for such a conversion is illustrated in Fig. 6, and consists merely of a single length of tinned copper wire, which is soldered to one of the screws securing the fixed plate to the panel, this wire being brought out to the opposite end plate of the main condenser and connected to one of the terminals in contact with the fixed plate. After assembling the dial, the knob proper is screwed on to the condenser spindle and secured with a set-screw, as illustrated in Fig. 2. In use the main part of the condenser is controlled in the ordinary way by rotating the knob, fine tuning being imparted by movement of the hand lever connected to the dial.

An alternative method is to leave the knob and dial in touch with the moving plate by means of the lever. Either plan gives very good results in practice. In a general sense any small variable condenser will act as a vernier if it be shunted across the ordinary type of variable condenser. *See* Billi Condenser; Condenser.

VERNIER DEVICES. This term embraces numerous mechanical arrangements for imparting slow motion to a control.

One of the simplest devices for the home constructor is illustrated in Fig. 1. It consists of an ebonite rod, about 9 in. long, with a tapered brass blade about 3 in. in length, attached to it. It is used as shown in Fig. 1, by resting the end of the blade on top of the panel and using the rod as a lever to move the pointer of a filament resistance. It will be found that if the lever is simply lifted, the movement imparted to the knob will be very small, thus providing fine tuning.

The most convenient method of making this lever consists of first cutting the blade to a taper shape and cleaning off the edges. An ebonite rod, $\frac{1}{2}$ in. in diameter and 9 in. in length, has a slot cut in the end with a hack-saw, as shown in Fig. 2. The blade is then inserted into the slot, two holes drilled through the ebonite, and the blade secured by careful riveting. The method of using this vernier lever for the fine tuning of a condenser dial is shown in Fig. 3, the end of the blade being inserted between the dial and the panel and the lever twisted. Thus a very small motion is imparted to the condenser knob or dial and fine tuning results.

Another type of detachable vernier arrangement, illustrated in Fig. 4, has a long ebonite rod provided with a rubber disk at the extremity. This is inserted into a bushed hole on the panel in such a way that the rubber disk bears against the rim of the condenser dial, so that

SIMPLE VERNIER DEVICE

Fig. 1. In this device a tapered brass blade is employed which enables a very fine adjustment to be made

by slowly rotating the vernier a very small amount of motion is imparted to the condenser.

The bushes are easily made up from terminal nuts, which may be shouldered and pressed firmly into holes drilled and counterbored in the panel, as shown in Fig. 5. These should be placed at such a distance from the rim of the dial that the rubber disk or wheel will press firmly against the latter. The components of the vernier handle consist of an ebonite rod about 9 in. in length, and one end should be drilled and tapped for a piece of screwed rod which is fitted into it. One end of this screwed rod is turned down so as to provide a smooth end. A solid disk of rubber about $\frac{1}{4}$ in. thick and $\frac{3}{4}$ in. in

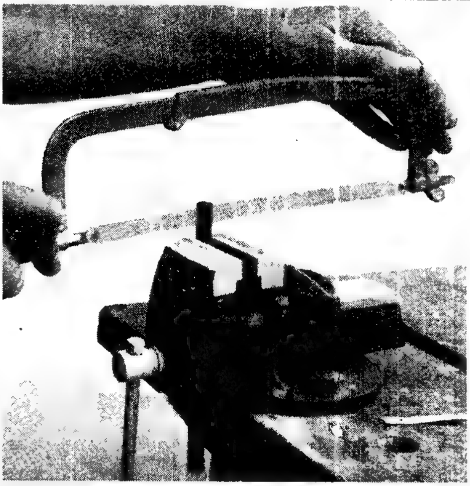


Fig. 2. An ebonite rod has a slot cut in it with a hack-saw to receive the metal blade for the vernier control

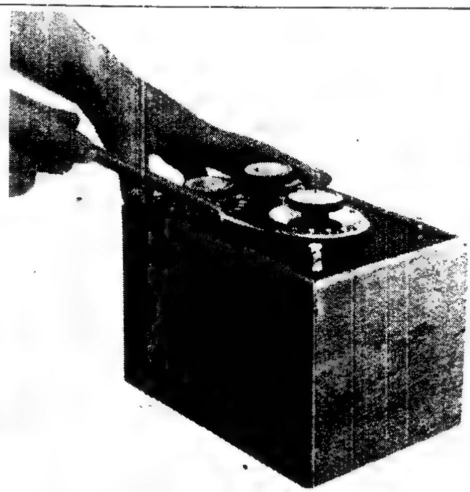


Fig. 3. How the vernier control lever is used to obtain fine adjustment of a condenser

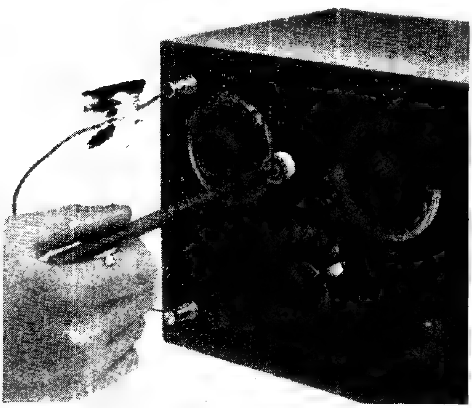


Fig. 4. In this control an ebonite rod with a rubber disk at one end provides fine movement of the dial

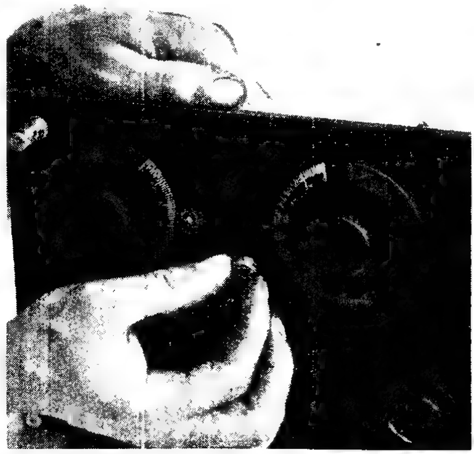


Fig. 5 Here the panel holes are drilled and counterbored to receive the vernier control shown in Fig. 4

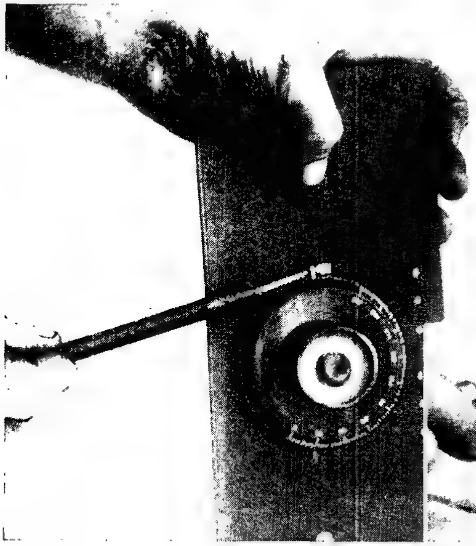
FINE ADJUSTMENTS OBTAINED BY USING VERNIER CONTROLS

diameter is then grasped between washers and another nut placed on the end of the rod and the whole assembled.

A good example of an amateur-made worm-driven vernier device is illustrated in Fig. 6. This consists of a simple worm formed on the end of an ebonite rod. A little angle bracket of brass is attached to the ebonite panel on the set, and drilled to receive the end of the worm shaft. Teeth are then cut in the worm and the dial, so that when the worm is rotated the dial is moved a very small amount. The worm is detachable, and can therefore be used to control several dials, providing they are cut with teeth. It will be found quite effective if the teeth are cut with a three-square file, as illustrated in Fig. 7. The notches should be uniformly spaced and of equal depth.

The spacing should be determined with the aid of a pair of dividers, which may be used to scratch the edge of the dial where it is to be notched.

The worm can be made from an ordinary wood screw by choosing one which is comparatively small in diameter, such as a No. 4, about $1\frac{1}{2}$ in. in length. The



WORM-DRIVEN VERNIER CONTROL

Fig. 6 (above). Amateur-made worm-driven control which is simple and efficient in use. Fig. 7 (right). Cutting teeth on the dial for control with the worm-driven device

pointed end is cut off, and the thread filed away to form a peg to fit into the hole in the angle plate. The head of the screw is then cut off, and the shank inserted in the hole drilled in the end of the ebonite rod, and fixed thereto by means of set-screws.

The notches in the rim of the dial are greatly improved if the dial be unscrewed from the condenser spindle and arranged to rotate on a simple peg. The worm is then brought into engagement with the notches on the rim of the dial, and rotated as rapidly and steadily as possible, either by hand or with the aid of a brace and bit. This has the effect of smoothing and more accurately shaping the teeth of the worm wheel, which will result in a much smoother action. *See* Condenser; Fine Tuning Devices.

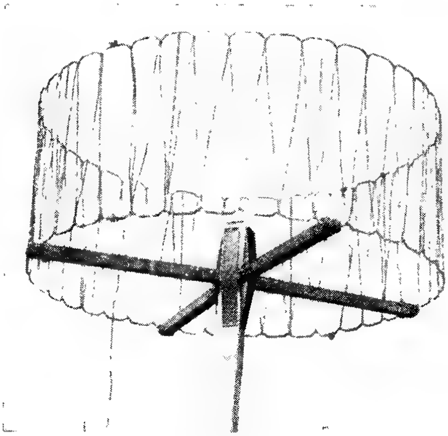
VERTEX AERIAL. The name of a patented aerial consisting of a drum-like structure built up in sections and covered with mesh wire. The example illustrated shows the simple way in which this aerial may be erected on a pole set upright in the ground, or attached to the roof of a house. The framework of the aerial is of galvanized iron wire. The drum measures about 4 ft. across and 1 ft. deep.

Four insulated cross-bars are connected to the frame and are united in the centre, where they are provided with plates for attachment to the pole. *See* Aerial; Frame Aerial.

VIBRATION GALVANOMETER. Type of galvanometer in which the moving element is adjusted to work or vibrate in resonance with the alternating current which is being measured. Such galvanometers are the most sensitive means of detecting and measuring minute alternating currents, and, further, they are selective in the sense that they do not readily respond to any components of the current the frequencies of which are not of the resonance frequency.

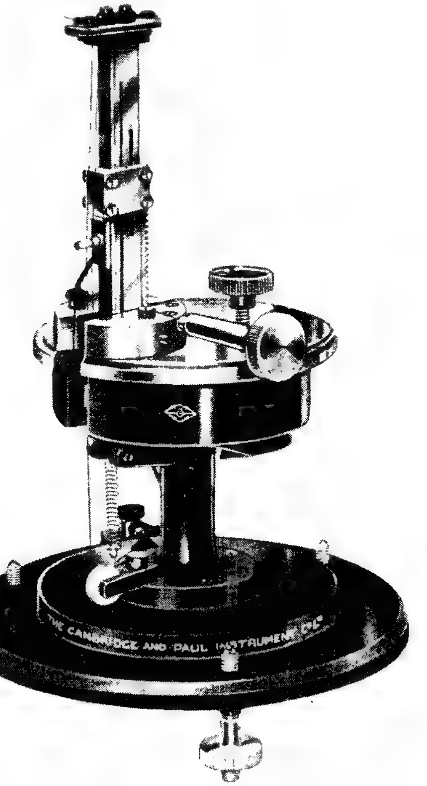
One of the best-known types of vibration galvanometer is the Campbell pattern, illustrated in Fig. 1. This pattern is notable for possessing an inductance of a low order and a moderate effective resistance, while it is readily tuned to frequencies between forty and one thousand periods per second.

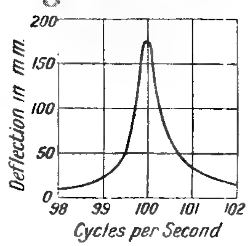
The moving element consists of a very narrow coil having a low moment of inertia, held within the air gap of a permanent magnet by a system of double bifilar suspension. The upper portion of the suspension system is adjustable by rotating a pinion which moves a rack.



VERTEX AERIAL

This is a patent form of aerial which may be easily erected and has no directional effects





VIBRATION GALVANOMETER
Fig. 1 (above). In this instrument the moving element is adjusted to vibrate in resonance with the A.C. being measured. Fig. 2 (right). Resonance curve of vibration galvanometer

Fig. 1, Courtesy Cambridge and Paul Instrument Co., Ltd.

Attached to the rack is a slide-block upon which are mounted two phosphor-bronze wheels, between which the suspension rests. Thus the length of the suspension may be varied to any point within the limits imposed by the rack without fear of breakage.

Further suspension adjustment is provided by which the tension may be varied. The latter motion is applied to the lower suspension. By suitably carrying out these adjustments for different supply frequencies, it is possible to make the instrument vibrate in resonance with any of the frequencies before mentioned.

The moving coil itself has a resistance of 12 ohms, and the suspension has one of 12 ohms also. Attached to the coil is a plane mirror which reflects the light through a lens having a focus of 100 centimetres. A movable cover is supplied with the instrument.

A curve showing the sharpness of the resonance obtained with these instruments appears in Fig. 2. The high sensitivity is due to reducing the damping to a very small amount, and if the full sensitivity is to be employed the frequency must be kept constant. In cases where this is impossible it will be found desirable to flatten the resonance curve by inserting a suitable shunt in the circuit. *See* Galvometer; Moving-coil Instruments.

VIRTUAL VOLTS. Readings of alternating current values based on the root mean square of the average values of their electro-motive forces. *See* Root Mean Square.

VOLT. The unit of electro-motive force. The practical unit of E.M.F. or potential difference is the International volt. It is defined as being that electro-motive force which, when steadily applied to a conductor having a resistance of one International ohm, creates in it a current of one International ampere. The potential difference between two points on a conductor may be measured in terms of the work done in conveying a unit quantity of electricity from one point to the other. In general $E = W/Q$, where E is the potential difference in volts, W the work done in joules, and Q the quantity of electricity measured in coulombs. *See* Ampere; Electro-motive Force; Ohm; Resistance; Units.

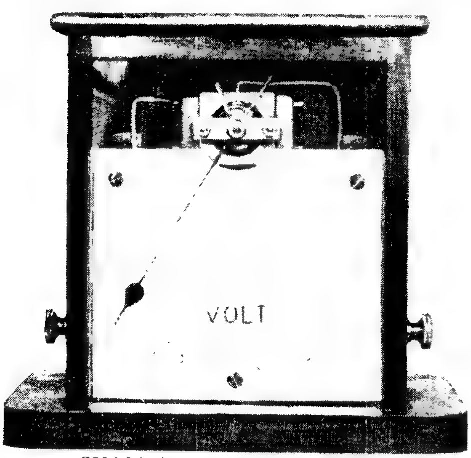
VOLTAGE TESTING OF INSULATORS. Method of testing insulators by which their breakdown strain may be ascertained. The materials of which insulators are made must necessarily be tested from time to time to ensure uniformity of their important electrical function. Apart from the actual material of which the insulator is composed, its shape and the conditions under which it is to be used are important factors upon which its efficiency depends. For instance, a porcelain cylinder with a perfectly smooth and plain exterior will, if exposed to damp or wet weather, allow current to leak around its surface, even though no current is actually passing through its body. For this reason insulators which are exposed to the atmosphere, or which have high voltages to contend with, are ribbed or grooved on their outer surface in order to prevent surface leakage.

When such insulators are under test, it is important that the test be made under the most adverse conditions that the insulator is ever likely to experience. To this end, high voltages are applied across the insulator under test and at the same time water is liberally sprayed upon its surface in order that no doubt may exist about its insulating properties under exceptionally bad conditions. *See* Insulation; Insulator.

VOLTAIC CELL. Primary cell in which chemical energy is converted into electrical energy. Most of the voltaic cells are separately described in this Encyclopedia under their own titles *e.g.* Clark Cell. *See also* Primary Cell.

VOLTMETER. An instrument for measuring the potential difference between two points of a conductor. There are many forms of voltmeter so far as external appearance is concerned. Those principally used by the amateur for wireless work are often of the watch type, so called because the mechanism is enclosed within a case similar in appearance to a watch. In others, such as that shown in Fig. 1, the mechanism is enclosed within a polished wood case.

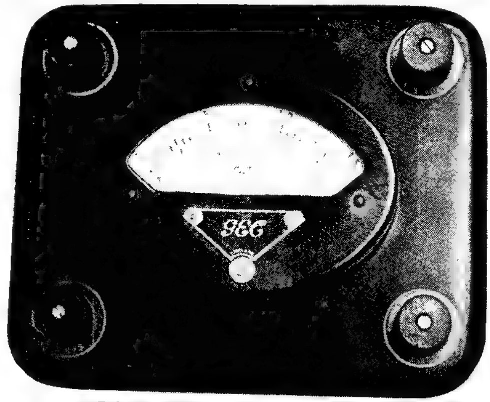
As a fixed instrument, such as might be mounted upon a panel or charging-board, a pattern similar to that illustrated in Fig. 2 would be very serviceable, the case being made entirely of metal, having a glazed window for inspection of the pointer and dial. Apart from their size, however, voltmeters and ammeters are very much alike, the internal construction of these instruments being described in this Encyclopedia under the headings Ammeter, Hot-wire Instrument and Moving-coil Instrument.



SMALL VOLTAGE VOLTMETER

Fig. 1. This instrument is used for registering small voltages, and is adjusted to shew fractions up to one volt

Courtesy J. J. Griffin & Co., Ltd.



DOUBLE-RANGE VOLTMETER

Fig. 2. In this type of instrument voltages from 0 to 3 may be measured, or from 0 to 30, as may be required

Courtesy General Electric Co., Ltd.

The essential difference between a voltmeter and an ammeter is that the voltmeter is a high-resistance instrument. This is because the voltmeter has to be connected in parallel with that part of the circuit where the potential difference is to be measured. The usual type of voltmeter is calibrated to cover a comparatively limited range of voltages. When, however, one instrument is to be used to cover considerably divergent voltages, such, for example, as the requirements of the low-tension battery, a commonly adopted plan is to provide an instrument with a series resistance. Means are provided, by the use of separate leads, by a small switch, or other convenient means, to enable one or other part of the circuit to be used at will. The one part would be proportioned to read for the lower-range voltages, and when the resistance is brought into play the higher voltages can be read.

A double-range instrument of this type is illustrated in Fig. 2.

It should be remembered that to function properly the voltmeter has to be very accurately made and well balanced, and should therefore be treated with every consideration and be preserved from mechanical or electrical shocks of any magnitude. *See* Ammeter; Galvanometer; Hot-wire Ammeter; Moving-coil Instrument; Wattmeter.

VREELAND ARC. Method of generating undamped oscillations from a direct current supply, due to F. Vreeland. A special mercury vapour tube is used, having one mercury cathode and two carbon anodes. The latter are arranged in parallel through choking inductances and resistances and an oscillation circuit is connected between them. The coils forming the inductance in the latter circuit are arranged that their magnetic fields cause a direct deflection of the stream of mercury vapour toward one or other of the carbon anodes. The oscillations are maintained in a steady state by the discharge of the condenser through the inductance coils.

VULCANIZED UBBER. Name given to the hard rubber largely used for insulating purposes in wireless. *See* Ebonite; Vulcanite.

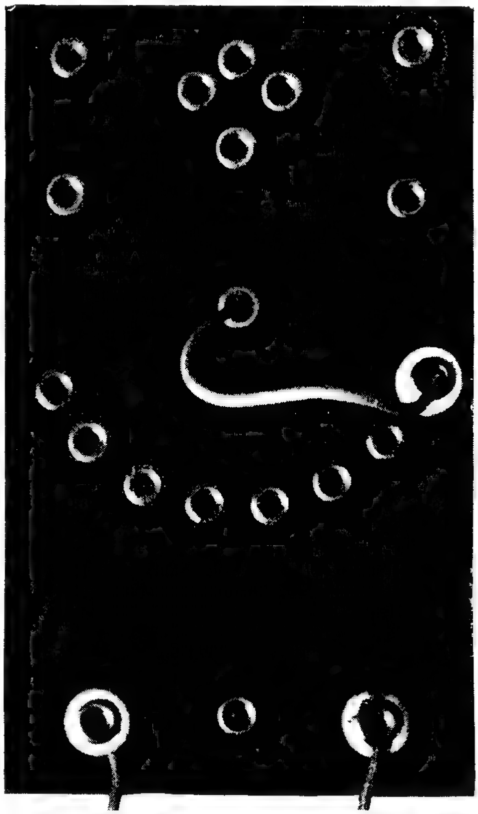
VULCANITE. Name given to hard vulcanized rubber, better known in wireless as ebonite or hard rubber. In the construction of the material pure rubber is mixed with about one-third of sulphur by weight and then heated up to 300 F. for a considerable time. For wireless purposes vulcanite is usually black and is supplied in sheets of convenient thickness. The outer skin often has poor insulating properties and in the construction of wireless instruments is best removed. This may be done by rubbing the surface on either side with glass or emery paper, as described under the heading Ebonite.

W

W. This is the chemical symbol for the metal tungsten, largely used in wireless for filaments of valves and for electrodes of spark gaps. *See* Tungsten.

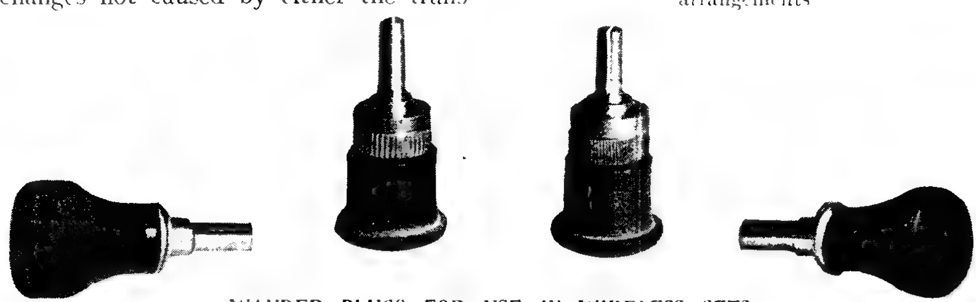
WANDERING. The alteration of apparent direction of received signals due to changes not caused by either the transmitting or the receiving station. *See* Fading.

WANDER PLUG. Name given to a small metallic plug usually fitted with an insulating handle or knob. Some types of wander plugs are illustrated in Fig. 2. The plug end is usually tapered and has a saw-cut along the tapered portion, thus assuring a good tight fit into its socket.



PANEL WITH PLUGS AND SOCKETS

Fig. 1. Wander plugs and sockets are fitted to this panel for ease of alteration in circuit arrangements



WANDER PLUGS FOR USE IN WIRELESS SETS

Fig. 2. Above is shown a group of wander plugs such as are largely used in wireless in connexion with tapped high-tension batteries. A black plug is used for the negative and red for the positive tappings

The plugs illustrated to the outside left and right have a solid knob having a screwed hole into which the plug portion screws. The connecting wire is twisted round between the pair of brass washers. In the central wander plugs in the illustration the knob in each case is hollow, and permits the connecting wire to pass through the hole.

The wander plug is largely used with the high-tension battery for rapidly selecting the required value of potential. Another and similar use allows the correct adjustment of grid bias to a valve. A convenient method of obtaining this is illustrated in Fig. 1, which shows a valve panel arranged for use with plugs and sockets. *See* Plug; Socket.

WASHERS. Name given in wireless to the flat ring of metal, ebonite or other material placed between a nut and the surface against which the nut is tightened for obtaining a required effect. In wireless the washer is largely used, and in many different connexions and for various purposes. One important application is its use as an insulating washer between two electrical conductors. A common usage in this direction is with insulating terminals secured to a wood or other semi-conducting panel, where a washer of ebonite, celluloid or mica is placed between the terminal and its point of contact with the panel.

The spacer washer is extensively used in wireless in the construction of the variable condenser. In this case the washer is of a definite thickness, and spaces each adjacent pair of condenser plates.

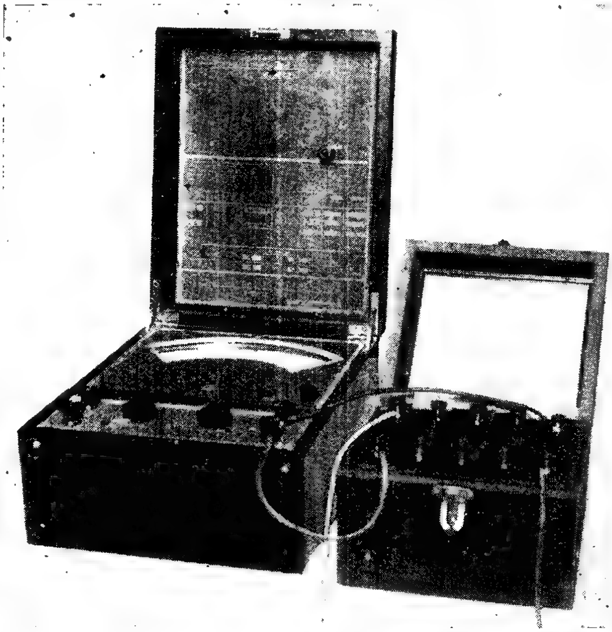
The spring washer usually consists of a phosphor-bronze spring used on the spindles of moving parts such as filament resistances and variable condensers. *See* Air Condenser; Spacer Washer.

WATT. Unit of electrical power. It is the equivalent to the work done at the rate of one joule per second. A kilowatt is a thousand watts, and 746 watts equal one horsepower. The commercial unit of electric work is the watt-hour. It is the work done in one hour by a current of one ampere flowing between two points of a conductor having a difference of potential of one volt. One watt-hour equals 3,600 joules = 2,654 foot-pounds. This unit is too small in practice usually, and the legal unit of electrical energy is the kilowatt-hour or Board of Trade (B.O.T.) unit, sometimes called the kelvin, equal to 1,000 watt-hours. *See* Joule; Units.

WATTLESS CURRENT. When a circuit is so inductive that the A.C. current lags practically 90°, or when the circuit has such a capacity that the current leads practically 90° over the volts, the current is said to be a wattless current.

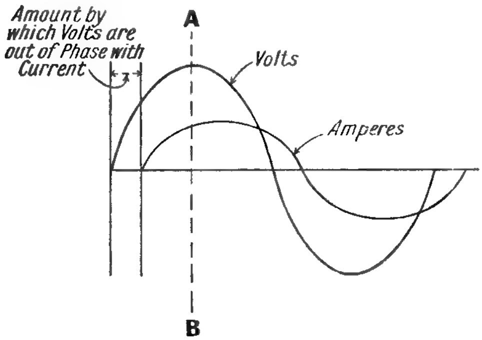
At any instant the power = E.C. cos ϕ watts, where E is the pressure in volts, C the current in amperes, and ϕ the angle of lag or lead. If ϕ is 90°, cos ϕ is zero. The net work done in the circuit is zero except on account of the resistance. Wattless currents do no useful work, though the current still flows in the circuit.

WATTMETER. An instrument for indicating in watts the rate at which electrical energy is being consumed in any part of a circuit at any particular instant. In direct current work the wattmeter finds little application, for the measurement of power or watts becomes simply a matter of



SUMPNER WATTMETER

Fig. 1. With the Sumpner wattmeter a quadrature transformer is always used. In the illustration the latter appears in the smaller cabinet on the right

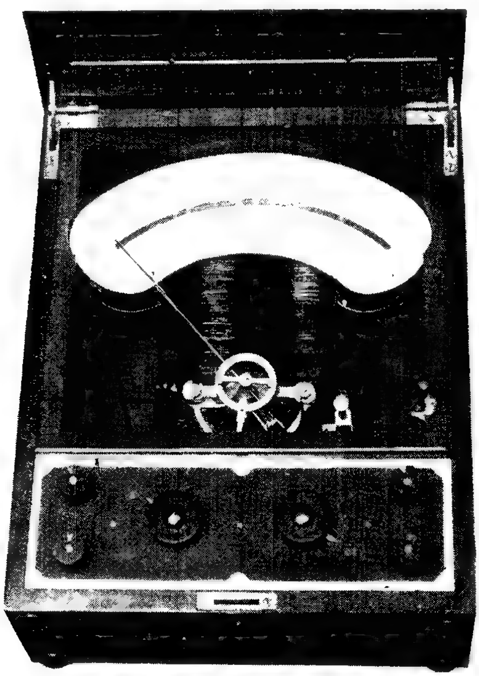


A.C. AND E.M.F. CURRENTS

Fig. 2. In this diagram the lag of the E.M.F. behind the alternating current is illustrated

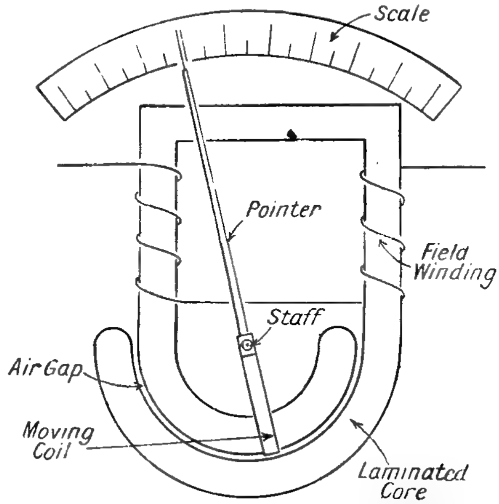
multiplying the amperes by the volts, as shown on an ammeter and voltmeter. In alternating current work, however, this simplicity does not obtain, for it is very seldom that the pressure (volts) is in phase with the current (amperes), and the angle by which the current lags or leads with respect to the pressure must be taken into consideration.

This condition is illustrated in Fig. 2, where the curves of an alternating current



DETAILS OF THE WATTMETER

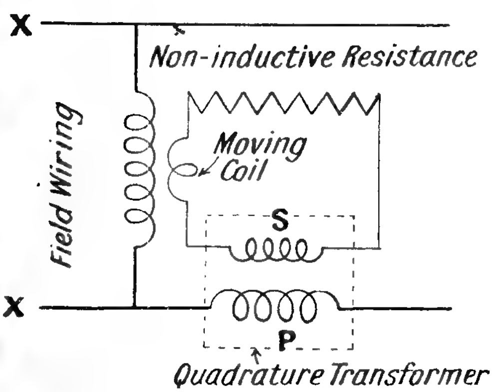
Fig. 4. This instrument is due to Dr. Sumpner, and is one of the best-known and most widely used wattmeters for measuring the rate at which energy is being consumed



SUMPNER WATTMETER THEORY

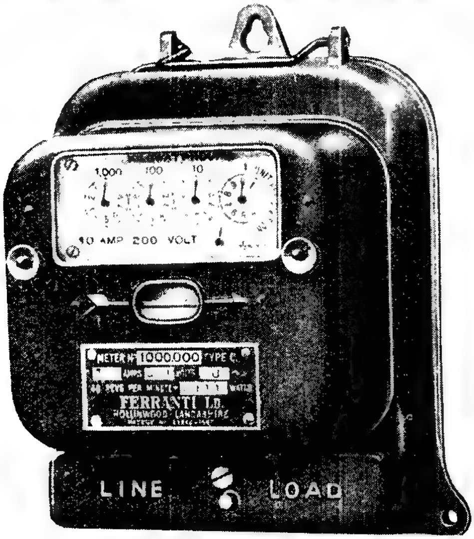
Fig. 3. This illustration portrays the working parts and the principle of the action of the Sumpner wattmeter

and electro-motive force are plotted out together on a time base. They are shown with the current lagging behind the pressure, which is the condition generally found in normal A.C. circuits. Assuming that in the circuit which is here diagrammatically portrayed a voltmeter gave a reading of 100 and the ammeter 5, then the " apparent " watts are 500. This is the number of watts that are actually being generated by the alternator, but it is not the number that are actually being consumed by the load on that circuit. The latter value, which is the one desired, is shown in the diagram by the line A B, which is a line



WIRING OF THE WATTMETER

Fig. 5. This diagram shows the wiring of the Sumpner wattmeter shown in Fig. 1, and is self-explanatory



FERRANTI INTEGRATING WATTMETER

Fig. 6. This example registers up to 1000 kilo-watt-hours at a maximum of 10 amperes and 200 volts

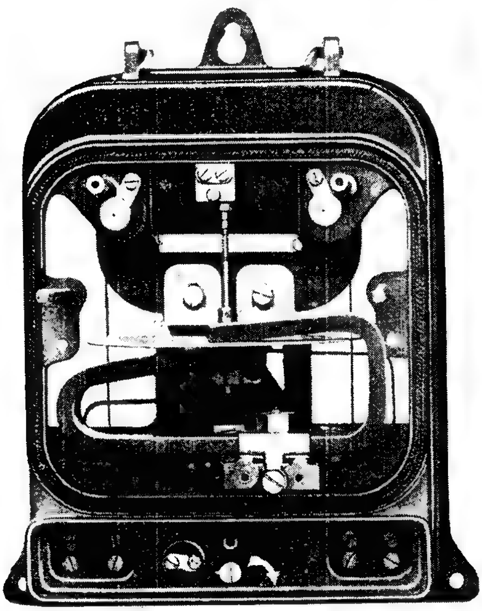
Courtesy Ferranti, Ltd.

drawn vertically through the ampere and volt curves, and crosses both, therefore, at the point where one is assisting the other.

If the true watts are to be ascertained, it is essential that an instrument be used which itself takes the power factor into consideration and indicates the "true" watts and not the "apparent" watts. The latter figure is always in excess of the former, and the power factor can never exceed the value of 1, and is usually ·7 or ·8.

An early form of instrument that functioned as a wattmeter was the Kelvin electrostatic balance. This was of practically no commercial importance as a measuring instrument, and required calculation after obtaining readings to ascertain the measurements required.

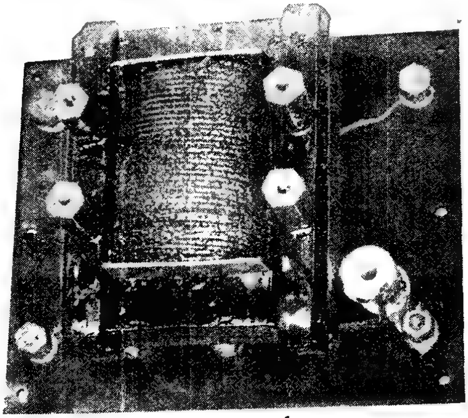
One of the best known and widely used commercial indicating wattmeters of to-day is that invented by Dr. Sumpner and manufactured by the General Electric Company. This is illustrated in Fig. 1 in the form of a portable instrument, while a circuit diagram appears in Fig. 5. In Fig. 3 is given an explanatory diagram of the mechanism of this instrument, and this illustration and Fig. 4 should be studied together. Referring, now, to Fig. 3, it is clearly shown that between the poles of a peculiarly shaped electro-magnet a moving coil, wound upon a light rectangular former, swings. The core of the electro-magnet is laminated, and it carries at its upper ends two windings, one on each limb. A pointer is attached to the staff of the moving coil, and both swing together. Control is effected by the usual phosphor-bronze hair-springs, but these have not been shown in the diagram, Fig. 3, for the sake of clarity, although they appear in Fig. 4.



INTERIOR VIEW

Fig. 7. Front interior view of the Ferranti integrating wattmeter, showing the electro-magnet and control magnets

Courtesy Ferranti, Ltd.



QUADRATURE TRANSFORMER

Fig. 8. Internal construction of the quadrature transformer as used with the Sumpner wattmeter is shown here

Courtesy General Electric Co., Ltd.

When this instrument is used as a wattmeter the field windings of the electro-magnet are connected directly across the mains, while the moving coil forms part of a closed circuit, which includes also a non-inductive resistance and the secondary of a quadrature transformer. These connexions are clearly indicated in Fig. 4.

The quadrature transformer forms part of the essential equipment of the Sumpner wattmeter, and is illustrated connected to the instrument in Fig. 1, a further illustration, showing its internal construction, appearing in Fig. 8. For the correct operation of the wattmeter it is essential that the current in the moving coil circuit be strictly proportional to that in the main circuit and in quadrature with it, and it is to satisfy these conditions that the quadrature transformer is used. In the design of this transformer a long air gap is introduced between the central limbs of the E-section iron laminations. The net result of this feature is to bring the magnetic flux to be practically co-phasal with exciting ampere-turns.

An air-cored transformer would, of course, fulfil this condition, but the iron core plays the important parts of reducing the magnetic reluctance of the circuit and thereby reducing the size of the instrument (important for portability), and also of shielding the windings from stray magnetic fields. The moving coil of the wattmeter has a resistance whose value is such that its self-inductance may be considered negligible, therefore the current in the secondary circuit of the transformer (to which the moving coil is connected) will be co-phasal with the electro-motive force, and therefore in quadrature with the main current.

There are actually four primary windings, each individually connected to the terminals on the upper panel, while there is only one secondary. The primary windings should be selected according to the different current values in the main circuit, directions for their coupling being given on the blue print inside the lid of the instrument.

With regard to the design of the wattmeter itself, there are three conditions which must be fulfilled. These are:

(1) The field of the magnet within the air gap must be uniform throughout the whole working range, and to this end very precise manufacturing methods must be used.

(2) The resistance drop in the field winding must be sufficiently small to allow the counter electro-motive force to be practically equal to the P.D.

(3) The field at any point within the gap must be strictly proportional to the total flux.

Wattmeters of the type described possess considerable advantages over other systems (such as the electro-dynamometer) in that they are substantially independent of frequency, wave-form and external magnetic fields. On the other hand, they are not adaptable to range-extensions by the application of external apparatus or by altering internal connexions.

The instrument illustrated may alternatively be used as a voltmeter by the simple expedient of using different connexions and rotating the knobs shown on the lower panel of the instrument to their other position. The latter adjustment causes an internal switch to move, and alters the connexions within the instrument to conform to the purpose indicated. Figs. 6 and 7 show the Ferranti integrating wattmeter. It registers up to 1000 kilowatt-hours, with maximum amperes of 10 and a voltage of 200. Fig. 6 shows the external view and Fig. 7 the view of the front with the case removed. *See* Ammeter; Electro-dynamometer; Power Factor; Voltmeter.

WAVE-LENGTH. The distance between corresponding phases of consecutive waves in a wave train measured in the direction of propagation at any instant.

The wave-lengths and frequencies of the most important ether waves are given in the table below. *See* Frequency; Waves.

Ray or Wave	Frequency	Wave length.
Gamma rays	3×10^{19} cycles	·00000001 mm.
X-rays	$4·7 \times 10^{15}$,,	·0000638 mm.
Ultra-violet rays	3×10^{15} ,,	·0001 mm.
Violet light rays	$8·33 \times 10^{14}$,,	·00036 mm.
Blue ,,	$6·6 \times 10^{14}$,,	·000451 mm.
Green ,,	$6·1 \times 10^{14}$,,	·00049 mm.
Yellow ,,	$5·1 \times 10^{14}$,,	·000588 mm.
Orange ,,	$4·6 \times 10^{14}$,,	·000652 mm.
Orange-red	$3·8 \times 10^{14}$,,	·000789 mm.
Red	$2·7 \times 10^{14}$,,	·0008 mm.
Infra-red		Down to 1 mm.
W.T Waves	6×10^{6} ,, to 2×10^{4} ,,	50 metres to 30 kilometres in common use.

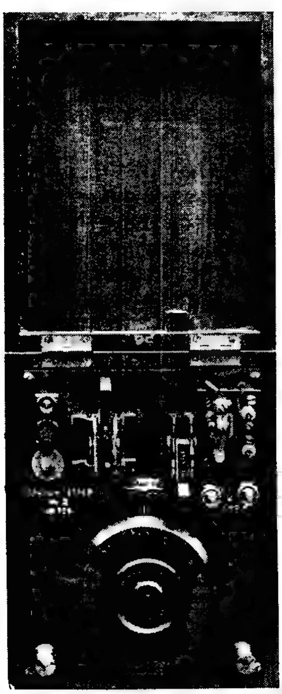
WAVE-METER: ITS THEORY AND CONSTRUCTION

How to Use and Make Instruments which Help Accurate Tuning

To the wireless experimenter the wave-meter is a most useful instrument and a knowledge of its principles is invaluable. Full details for the construction of a wave-meter are included. Reference should also be made to the heading Waves, and to such cognate headings as Broadcasting; Frequency; Transmission, etc.

A wave-meter is an instrument for measuring wave-lengths. Before passing to the construction of wave-meters and the methods used it is important that the relationships of velocity, frequency and wave-length should be fully understood. In the first place, electro-magnetic waves travel through the ether at the speed of light, which is 3×10^{10} centimetres per second, or approximately 186,000 miles per second. The field formed by these waves possesses a rhythmic character, having a certain definite frequency, the latter depending on the characteristics of the oscillator by which they are generated.

It is apparent that no useful purpose is served if the wave-length of the waves through any oscillatory circuit is ascertained, but on the other hand, if the frequency by which the waves are propagated at the place of transmission is found, the knowledge is of considerable utility, for by that means the wave-length may be ascertained with reference to a fixed known standard of velocity. The simplest method of effecting this is to utilize the inductive properties of the oscillatory circuit through which signals of unknown wave-length are passing to induce waves of a similar character in a wire whose length may be varied until a state of resonance exists between the two circuits.



MARK IV WAVE-METER

Fig. 1. Panel view of the Government Mark IV wave-meter. It is a very useful experimental instrument

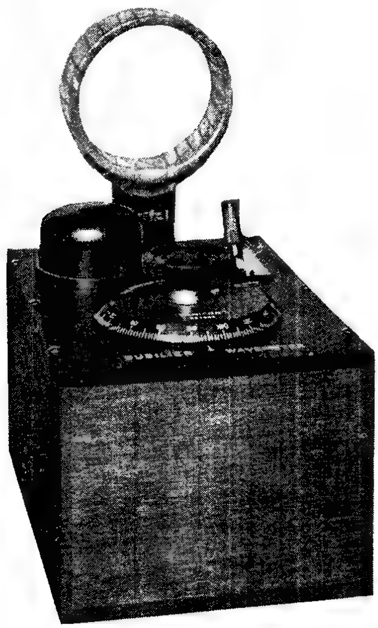
Obviously this system has many practical limitations, chiefly on account of size, and this drawback has led to the development of other types.

Most forms of wave-meter, as the ex-Government Mark IV instrument illustrated in Fig. 1, have a buzzer to provide an audible signal. The particular wave-meter illustrated is a three-range instrument, and gives direct readings from 100 to 2,000 metres. These different ranges are obtained by switching in or out a series of fixed inductances arranged within the cabinet. The switch which operates these changes is shown to the left of the top of the panel. A carborundum detector is fitted, and operates without the use of a potentiometer. The detector is simple in construction, a steel strip making contact on the crystal, and adjustment being effected by screwing up or down a small knob.

On the extreme right of the panel, at the top, is the buzzer. This is of the high-frequency type, and emits a note of a very high pitch and pure character. It is designed to work for long periods without change of pitch and quality, and works well off a single dry cell. To the left of the buzzer is another switch, by which it is possible to arrange the instrument to work with a transmitting or receiving set.

The terminals below the buzzer connect that component to the battery, while those at the bottom of the panel connect to the telephones. A similar commercial buzzer wave-meter is shown in Fig. 2. This type of wave-meter is very simple to use, its operation, in conjunction with a receiver, being as follows.

First of all place the wave-meter in some position near to the tuner of the receiver and start the buzzer into action. Do not connect the telephones to the wave-meter, but keep them on the receiver. It is now possible that the buzzing will be heard faintly in the receiving telephones, but whether this occurs or not, rotate the wave-meter condenser until it is heard at a maximum. This point will be found to be very sharply defined and readily distinguishable.



DUBILIER TYPE WAVE-METER

Fig. 2. This illustration shows a commercial type of wave-meter suitable for broadcast wave-lengths

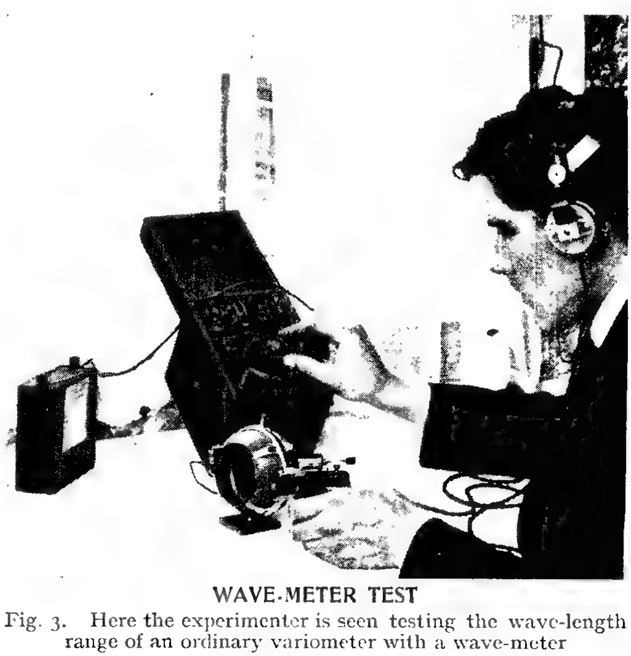
Should no maximum occur at all, but the buzzing be heard at about the same intensity throughout the whole period of condenser rotation, it is an indication that the wrong scale is in use, and that the switch which controls the ranges must be moved to another position.

When the maximum buzzer note has been heard, the reading at which it occurs will indicate the wave-length to which the receiver is set, for it shows that the two circuits are in resonance. Greater accuracy will result if the meter is placed sufficiently far away from the receiver to give the faintest audible buzz, for by this means the maximum will be more sharply defined, and no doubt will occur at which division on the condenser the optimum point occurs.

A useful function of the wave-meter lies in tuning a receiver to any desired wave-length within the range of the receiver. This obviates the process of searching for the station that it is required to receive, and makes only fine tuning necessary. The wave-meter is put into the "send" position, and connected to a suitable battery for operating the buzzer. The dial is then turned to the wave-length reading required and left with the buzzer in operation. The receiver is then tuned in the manner previously described until the transmitted oscillations of the buzzer are received at an optimum point.

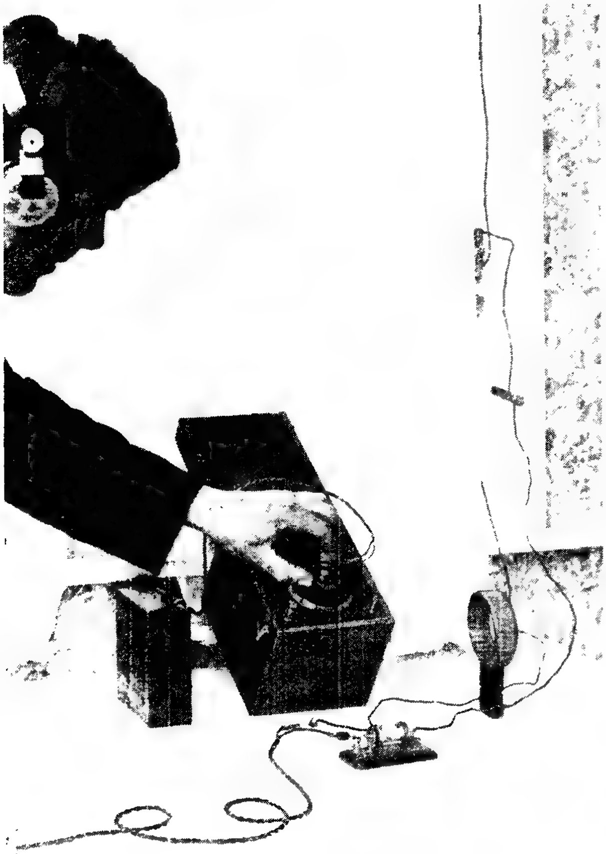
With the wave-meter, the maximum and minimum wave-lengths of a receiver or inductance can be measured. Fig. 3 shows the lay-out required for obtaining the wave-length range of a variometer. The wave-meter is set into operation in the manner employed in the last test. The variometer is connected in series with a crystal detector and a pair of telephones to form a closed circuit. Having obtained a good spot on the crystal, the wave-meter dial is rotated until the buzzing is heard at an optimum point. By simultaneous adjustment of the variometer and wave-meter controls, the optimum buzzing point can be regulated to the maximum and minimum limits of the variometer.

To find the fundamental wave-length of an open outdoor aerial two operations are required. The first determines the natural



WAVE-METER TEST

Fig. 3. Here the experimenter is seen testing the wave-length range of an ordinary variometer with a wave-meter



WAVE-METER TEST FOR AERIAL

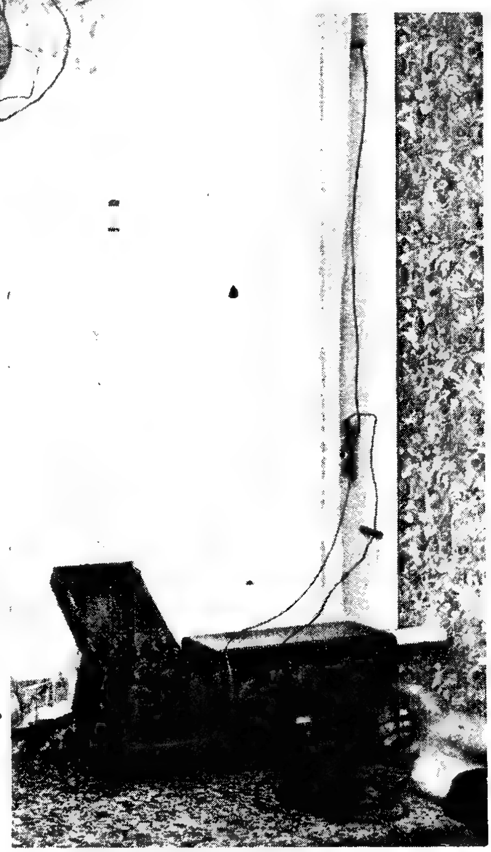
Fig. 4. In this photograph is shown the method of ascertaining the wave-length of an outdoor aerial, using an inductance coil of known wave-length. Note the connexions

wave-length of an inductance coil, in the manner employed for the variometer. The aerial and earth are connected to either side of the inductance, as shown in Fig. 4, and a fresh reading with the wave-meter taken. The difference between this reading and that of the coil itself gives the fundamental wave-length of the aerial and earth system.

Another use for the wave-meter is as a wave trap, where advantage is taken of its tuning elements. The buzzer and crystal detector are not required, and are omitted from the circuit. One application is illustrated in Fig. 5. In this the aerial and earth terminals of the receiving apparatus are connected across the wave-meter to form a parallel circuit.

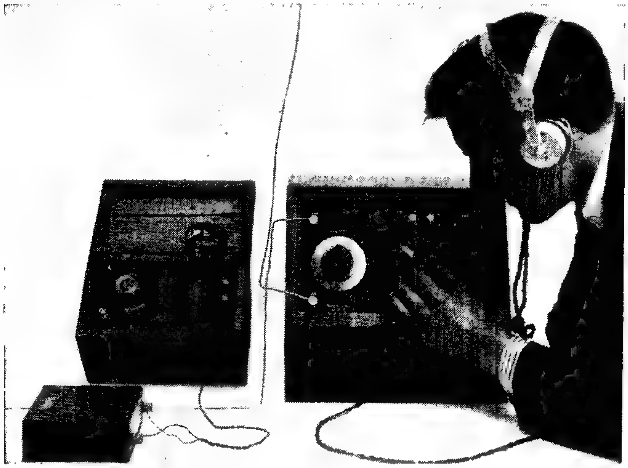
An essential feature with all wave-meters is that they should remain absolutely constant and stable, as regards their amounts of inductance, after they are once calibrated. To this end the inductances must be wound on formers of considerable mechanical strength in order that the effects of heat and damp will not cause warping and shrinking. A slight variation in shape will cause serious alterations in values.

The heterodyne wave-meter consists essentially of a valve oscillator having variable inductive and condenser components. By adjusting these values it is possible to make the circuit oscillate at any desired frequency between the limits imposed by the inductive and capacitative quantities.



USED AS A WAVE-TRAP

Fig. 5. Where interference from an unwanted transmitter is experienced the wave-meter may often be used as a wave-trap



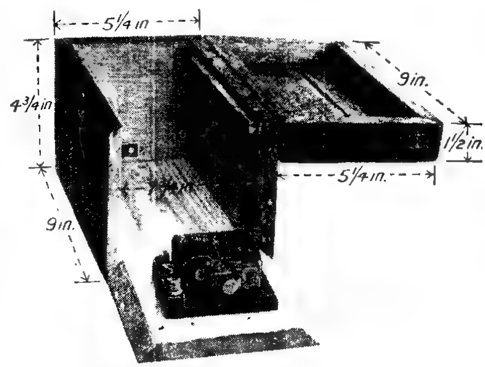
EXPERIMENTAL LAY-OUT

Fig. 6. Here is shown the lay-out required to tune a receiver to a definite wave-length of oscillation emitted from the wave-meter. Note the connexions here also

The wave-meter circuit is made to function and the condenser rotated until the well-known heterodyne whistle is heard in the telephones. The condition of resonance between the two circuits is indicated when the "nul" or silent point between descending and ascending whistles is obtained. An illustration of this form of wave-meter appears under the heading Heterodyne Wave-meter.

The main components required in the construction of a send and receive wave-meter include a duo-lateral coil, a crystal detector, a high-note buzzer, and a variable condenser of ·001 mfd. capacity. The variable condenser should be of the best quality, as an inferior make may tend to change its capacity after it has seen considerable usage. The buzzer used should be selected for its high and constant note.

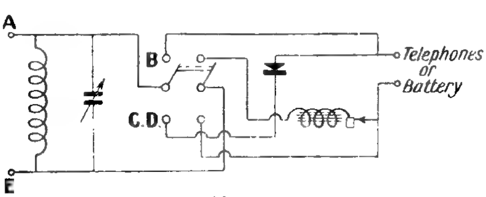
The completed wave-meter operating in conjunction with a receiving set is illustrated in Fig. 6. A substantial box fitted with a hinged lid, and with the right side of the box also hinged, is required. This should be made from $\frac{1}{2}$ in. prepared wood to the sizes given in Fig. 7. As shown in this illustration, the buzzer is secured to the inside of the hinged side, which is kept closed by means of a brass right-angle bracket screwed to the top of the front side of the box. A hole is drilled and tapped into the bracket on the side in contact with the hinged side. When the bracket is in position the hinged side is closed and a pencil mark is made corresponding to the hole in the bracket. A hole of clearance size is drilled over this mark, and permits a screw to pass through from the outside of the box. This screw may be made from a contact stud, through the head of which a short bar of stout brass wire is soldered. The position of the bracket and the screw used are also shown in Fig. 7.



CABINET FOR THE WAVE-METER

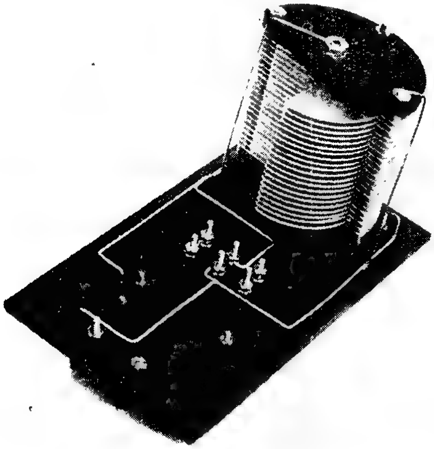
Fig. 7. The experimenter who wishes to construct a wave-meter at home will find the leading dimensions of the case here

A panel of $\frac{3}{16}$ in. ebonite is cut and made a tight fit to the inside of the box. All joints should be as dust-proof as possible to obviate the possibility of alteration of the value of the components. To the extreme left of the panel as it fits into the box with the lid at the back an aerial and earth terminal are placed to the back and front of the panel respectively. At the opposite end two terminals are required for connexion of the battery operating the buzzer and also for telephone terminals when the instrument is determining the wave-length of a transmission. To the left



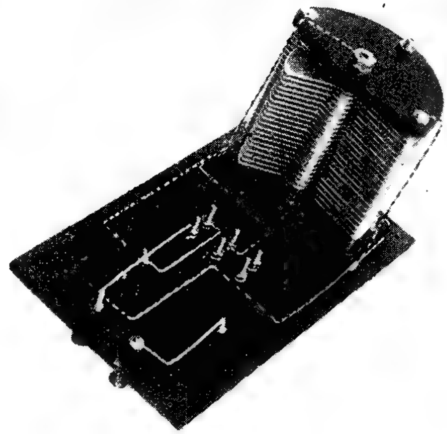
CIRCUIT DIAGRAM

Fig. 8. Wiring of the home-constructed wave-meter is carried out as here. This should be done in heavy-gauge wire



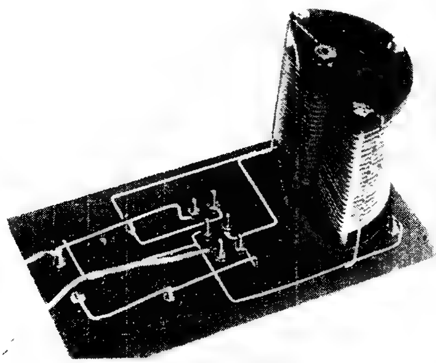
WIRING COMMENCED

Fig. 9. Here the tuning components are connected to the centre contacts of the switch and crystal detector



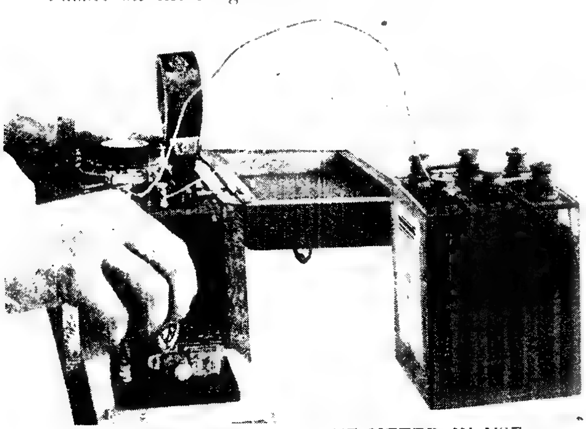
SECOND STAGE IN WIRING

Fig. 10. At this stage the instrument is completed as a means of measuring transmitted wave-lengths.



WIRING COMPLETED

Fig. 11. In this illustration the wiring is finished, the flexible leads connecting to the buzzer on the hinged side of the case



AMATEUR-MADE WAVE-METER IN USE

Fig. 12. Owing to the hinged side, to which the buzzer is attached, adjustment is easily accomplished

of the panel the variable condenser is attached. A miniature double-pole double-throw switch is secured to the right of the condenser, which brings the switch about central to the panel. A good quality crystal detector is mounted to the right side of the switch, behind which the coil holder for the duo-lateral coil is placed.

The wiring, which is carried out to the circuit diagram given in Fig. 8, should be effected with thick gauge wire, care being taken to see that it is quite rigid and free from vibration. The first part of the wiring is shown in Fig. 9, where the aerial and earth terminals are connected to either side of the condenser, the coil holder and the centre studs of the switch.

The next wiring operation completes the wave-meter for determining the wave-length of a station transmitting. Used in this way the instrument is simply a crystal receiver in which the variable condenser is used for determining the wave-length of the station being received. The terminals to the right of the panel, as it normally fits inside the box, are used for attachment of the telephones. This stage of the wiring is shown in Fig. 10. When the wave-length of a receiving set at any particular point of its tuning range is required, the wave-

meter is converted by means of the switch into a small transmitter, the oscillations of the buzzer being heard in the receiving set when they are in resonance with it.

The buzzer circuit is shown completely wired in Fig. 11, the flexible leads being attached directly to the buzzer terminals.

It will be seen that the hinged side forms a convenient means for adjustment of the buzzer. In the buzzer illustrated the locking screw is provided with a wide, curved slot enabling the screw to be operated by a coin, as shown in Fig. 12.

The best way to calibrate the instrument is to use a wave-meter of known accuracy, but if such is not available, the constructed wave-meter must be calibrated by the reception of transmissions of known wave-length. The arbitrary graduations on the condenser dial may be removed if desired, and the dial recalibrated in terms of wave-lengths. An alternative plan is to prepare a chart to be pasted into the lid in which the existing dial calibrations correspond to certain wave-lengths.

WAVES IN WIRELESS WORK AND THEORY

By Sir Oliver Lodge, F.R.S., D.Sc.

Here the well-known pioneer in the whole art and theory of wireless communication explains the fundamental theories and calculations underlying electro-magnetic waves and their radiation through the ether of space. Sir Oliver Lodge's introductory article on Waves (page iii) should be read in conjunction with this. See also Oscillation.

A wave is any disturbance which is periodic in both space and time. That is to say, the disturbance must repeat itself at regular intervals of space, which interval is called a wave-length; and must also repeat itself at regular intervals of time, which interval is called the period; while its reciprocal is called the frequency.

To take an example. The essential part of a corkscrew is periodic in space, the spires repeating at regular intervals. The distance separating the turns of the screw is called its pitch, which might be, say, $\frac{1}{4}$ in., and corresponds to wave-length. But as long as the corkscrew is stationary there is no periodicity in time, and therefore nothing that corresponds to a wave. But now let the screw be steadily rotated with a certain frequency, say three times a second. The period is one-third of a second, and the turns of the screw will now be advancing with a given wave-length, $\frac{1}{4}$ in., and a given period. The speed with which they advance will be the wave-length multiplied by the frequency, that is $\frac{3}{4}$ in. per second. It is easy to generalize from this example, and to say

$$v = n\lambda\text{; or, } \lambda = vT\text{;}$$

where v is the velocity of advance, n is the frequency, which is the same as $1/T$, the reciprocal of the time-period; while λ is the wave-length.

The simplest equation representing this kind of doubly periodic disturbance is

$$y = a \sin (qx - pt),$$

which means that the disturbance y is propagated along the axis of x with the velocity $v = p/q$; the wave-length being $\lambda = 2\pi/q$, and the period $T = 2\pi/p$. The frequency, of course, is $p/2\pi$; while a is the amplitude or semi-diameter of the corkscrew, representing its departure from the straight, the square of which in real wave motion, such as sound or light, represents the loudness of the sound or the brightness of the light.

The wave equation may also be conveniently written thus

$$y = a \sin \frac{2\pi}{\lambda} (x - vt)$$

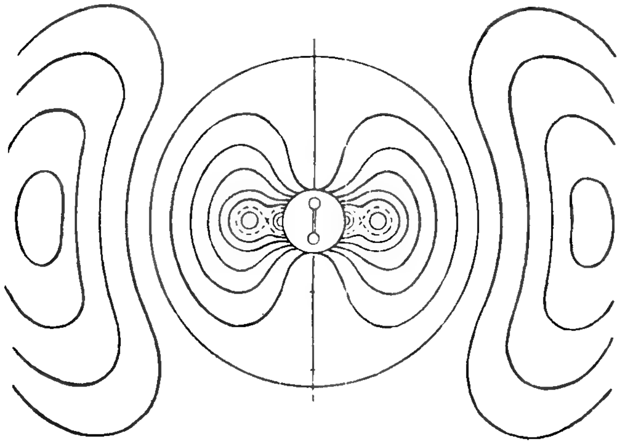
where the chief constants explicitly appear; and the frequency is v/λ.

The process of wave-propagation can be seen going on, in rather more complicated fashion, in the ripples on a pond or in the waves of the sea. The actual particles are heaving up and down, or revolving round and round, without locomotion. It is the wave form only which is progressive; there is no locomotion of anything material. And yet energy travels along a wave, being transmitted from source to receiver; as when sound produced at one place is heard or otherwise quenched at all places within hearing distance.

The fundamental equation to every kind of wave motion, travelling with the velocity v along the axis of x, is

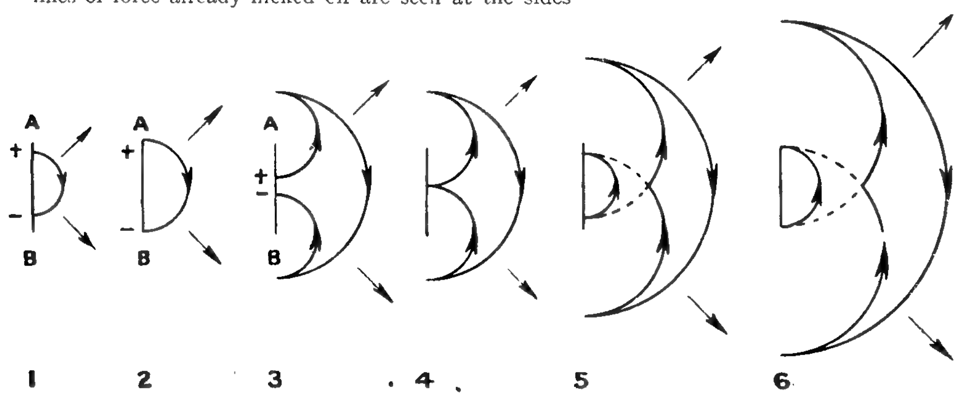
$$\frac{d^2y}{dt^2} = v^2 \frac{d^2y}{dx^2}$$

And it was the splendid discovery that the equations representing electric and magnetic disturbances could be combined into an equation of that sort which constituted



HERTZ'S THEORY OF WAVE RADIATION

Fig. 1. This figure represents one phase of the process of wave generation. A dumb-bell oscillator is seen at the centre and lines of force already flicked off are seen at the sides



DIFFERENT PHASES OF WAVE EMISSION BY AN OSCILLATING CHARGE

Fig. 2. In these figures the charges are oscillating up and down the rod AB, and the results on electric lines of force connecting them are seen.

Clerk-Maxwell's Electro-magnetic Theory of Light. For by combining electric and magnetic known relations—expressing the facts discovered by Faraday in a most ingeniously comprehensive and abstract manner—he arrived at the following (here simplified) equation

$$\frac{d^2F}{dx^2} = \mu k \frac{d^2F}{dt^2}$$

where F is any relevant electric or magnetic vector; and this showed him at once that electro-magnetic wave propagation was possible, and that the waves must travel with the velocity $1/\sqrt{(\mu k)}$, where k was the electric constant of the ether and μ its magnetic constant. Maxwell thereupon made experiment, and found that this speed of electric wave propagation—the speed corresponding to the product of the two ether constants—was the speed of light. That, then, is the equation of wireless waves, and of every other kind of wave which can exist in the ether of space—Hertz waves, radiant-heat, light, photographic rays, X-rays, gamma-rays, and all. They all go at e x a c t l y t h e s a m e pace, whether they are several miles in length or only a million-millionth of an inch. They differ in intensity and frequency, and they differ in simplicity and complication; but they differ not at all in speed.

The way to generate such waves directly was unknown to Clerk-Maxwell, though he knew that from time immemorial mankind had ignorantly generated them indirectly by making bodies hot, and that even animals could detect some short waves from sun and moon by that remarkable instrument, the eye. But after Maxwell's death FitzGerald suggested that the oscillations known to be produced by a condenser discharging through an inductance might excite such waves, of calculable wave-length, directly. And about 1887 and '88 Lodge imperfectly, and Hertz much more thoroughly and completely, succeeded in generating and detecting such waves. These waves of Hertz were the wireless waves which, through the enterprise of Senatore Marconi and his co-workers, have now covered the world.

All that is really essential for their emission is two separated capacity areas, one charged positively, the other negatively, which are then allowed to spark into each other through connecting rods. The essential identity of these waves with light can be shown, and was shown, by repeating with them many optical experiments, some form of coherer being used for their detection, as expounded by Lodge in his book called "The Work of Hertz and his Successors," published first in "The Electrician" for June, 1894, the said waves having been foreshadowed by him near the end of a paper in the "Philosophical Magazine" for August, 1888.

Hertz's Application of Clerk-Maxwell's Theory

Hertz was not only an experimenter, he was able to apply Clerk-Maxwell's theory so as to work out the wave's mode of origin and to exhibit its manner of propagation. Hertz's theory of the emission of waves from a radiator or transmitter is usually depicted as in Fig. 1.

This figure represents only one stage or phase of the process of wave generation. A dumb-bell oscillator is seen at the centre, and the lines of force which have already been flicked off it are seen outside. They form closed loops round which an electric disturbance is circulating, and their magnetic concomitant (not shown) is in loops perpendicular to the paper.

The whole diagram is a mere section or slice of the three-dimensional propagation outwards all round the axis, the circle is really a sphere. Inside the circle lines emitted still more recently are shown, and these are inflected so that they are soon going to break into two portions, one portion expanding outwards, while the rest returns to the oscillator. The detached portion may be likened to a curious kind of expanding vortex ring in the ether. The place of breaking off is the crossing point of the dotted line. The number of receding or restored lines is the same as the number of expanding lines, but their energy is diminished by that of the detached portions. These detached and afterwards independent portions carry energy out into space, and accordingly the original disturbance subsides, unless it is supplied with fresh energy.

These detached and advancing portions constitute the electric waves which travel with the speed of light, and affect coherers and valves when collected by receiving aerials. A set of diagrams of all the different phases can be drawn, and if these are then mounted in a stroboscope, or projected in a kinematograph, the oscillations can be seen going on, and the waves can be seen flicked off at a certain distance from the centre and thereafter continually travelling outwards as electromagnetic waves.

Hertz's working out for the theory of the emission of waves from a linear or dumb-bell oscillator is very complete; but we can simplify it, in the light of Poynting's Theorem, somewhat as follows.

Poynting's Theorem states that when alternating electric and magnetic lines of force, in the same phase, cross or intersect at right angles, energy advances with the velocity of light in a direction perpendicular to both, and of an intensity proportional to their product. The sense in which this wave energy advances, whether in the positive or negative direction, depends on the phase relation between the electric and the magnetic oscillations; and if the phase of one of them is reversed, the direction of propagation is reversed, too.

Poynting's Illustration of Wave Emission

Now think of the earth or a terrestrial globe with a conducting rod right through it along its polar axis, and then think of an electric charge, or of a pair of opposite electric charges, oscillating up and down this rod. When the positive charge is at one pole and the negative charge at the other, the line of force joining them is something like a line of longitude. This is the condition at the end of a swing. When the charges are rushing past the middle of the rod, it will be surrounded by magnetic lines, which correspond with the lines of latitude. On a terrestrial globe the lines of longitude and latitude intersect at right angles, and therefore it would seem that we could apply Poynting's Theorem to them forthwith, and say that energy advances radially from the globe in all directions. Roughly speaking, this is true. But looking at the matter more closely we find that initially the electric and magnetic lines do not intersect, for they are not in phase; they start with a quarter-period difference, and they have to expand before they get into step.

The conditions near the oscillator are therefore somewhat complicated, and the energy pulsates to and fro, first advancing, then receding. But beyond a certain distance, which is approximately a quarter wave-length, the magnetic and electric oscillations have got into step. Thenceforward they will be in the same phase, the lines will properly intersect, and the energy will advance wholly in one direction, namely, outwards along every radius of the sphere. But though it advances in all directions, its energy is not equal in all directions. The radiation intensity will be a maximum in the direction of the equator and zero in the direction of the poles, because it depends on interaction of both electric and magnetic forces, and because the magnetic force is a maximum at the equator and zero at the poles. Consequently the intensity of radiation will vary with the cosine of the latitude. Hence, for effective transmission in all directions over the earth's surface, an aerial should be approximately vertical.

Why Short Waves are more Efficient

Initially the intensities of the electric and magnetic forces vary according to a complicated law of distance, involving the inverse cube and other powers of the distance. But beyond a certain range, comparable to a wave-length, they have settled down to the simple law of inverse square; and after that the strength of the radiation will follow the usual law of emission of light.

The same kind of complication, close to a source, is true for luminous and all other emitters. But whereas in optical cases the radiators are exceedingly small—indeed of atomic dimensions, so that only refined observation can detect what is happening in their immediate neighbourhood—a radiating oscillator or aerial is a big thing, and consequently we are able to study the pulsations in its immediate neighbourhood. And true waves, travelling altogether outward, do not begin until a quarter-wave distance has been exceeded. This is the reason why short-wave emission is more efficient than long-wave. A low-frequency oscillator, such as an alternating dynamo, pulsating, say, 300 times a second, emits waves 100 kilometres long. Consequently the place where true waves originate is about 15 miles away, where the strength of the fields is insignificant; and accordingly its radiation is inappreciable.

Relation of Intensity to Wave-length

But if, instead of that, we consider an oscillator pulsating three million times a second, its waves are only 100 metres long, and the distance where waves originate is less than 30 yards. For a really small oscillator, such as Hertz used, the waves might be only 3 metres long, or, in extreme cases, 30 centimetres. The pulsations are then enormously rapid and the power of the radiation very great, so great that the energy is radiated away in the course of one or two swings, or most of it even in the fraction of a swing. That is why, other things being equal (which they never are), short-wave transmission is so effective.

But when obstacles and obstruction have to be encountered, long waves are able to ignore difficulties which would be fatal to short ones. Hence, in practice, there always has to be a compromise; and for really long distances long waves are usually best; in addition to the fact that a big oscillator has more energy at its disposal than a small one, though it does not get rid of it so quickly.

The way the intensity or power of the radiation depends on wave-length, from an oscillator of given size, was worked out by FitzGerald in 1883, long before even Hertz's discovery, though Hertz subsequently independently arrived at the same result, which may be expressed thus

$$\text{Energy radiated per second} = \frac{16\pi^4 c Q^2 l^2}{3k\lambda^4}$$

where Q is the charge accumulated in the capacity area at the end of the straight vertical rod or wire of length l; c is the velocity of light, k is the electrostatic constant of the ether, and λ is the wave-length. Here we see that the power of the radiation is proportional to the square of the height of the aerial, and inversely as the fourth power of the wave-length. This, applied to ordinary heat radiation, is equivalent to saying that the radiating power of a source is proportional to the fourth power of its absolute temperature.

I simplified this expression for radiating power in a paper in the "Phil. Mag." for July, 1889, as follows: Let the potential, in volts, to which the upper capacity-area is charged be V; let the aerial conductor be a straight rod of length l and diameter d, and include the necessary spark gap whose width represents the potential V. Then

calculate $\log_e \frac{4l}{d}$, and call this n; it is a mere number, usually in those days between 4 and 6, for the thick rod and dumb-bell shape then in vogue, and it is seldom more than 10 or 12 even now. Then the power of the radiation in watts is equal to

$$\frac{V^2}{360n^2 \text{ ohms}}$$

All simple emitters, large and small, radiate at approximately the same rate when supplied with the same spark gap; for the only difference between them is in the value of n, which changes but slightly. This simple expression for radiating power has not attracted attention, for it was published before the idea of using such radiation was mooted.

Early Work on Wireless Waves

A numerical example, given in my paper at the same time, is instructive. Let a dumb-bell oscillator consist of two spheres or plates joined by a stout rod and spark gap, such that $l = 25d$; it will have the characteristic number $\log_e \frac{4l}{d}$, equal to 4·5. Let its ends be charged to 26,400 volts when the spark occurs which starts the oscillations; then by the above simplified formula the dissipation resistance is 7,300 ohms, and the maximum power of the emitted waves will be 96,000 watts or 128 horse-power. At this rate the whole original stock of energy in the small oscillator contemplated would be gone in the two-hundred-millionth of a second, *i.e.* in the time of $1\frac{1}{2}$ vibrations; but, of course, the energy really decreases logarithmically.

Nothing approaching continuous radiation could be maintained at this great intensity without the expenditure of great power; that is why, in 1897, I introduced additional self-induction in the joining rod, so as to diminish radiation intensity in order to prolong it and render exact tuning and selective reception possible.

Even for some of the ordinary single-wire aerials of to-day, apart from introduced self-induction, when the height is, say, 4,000 times the diameter of the conductor, the value of n or $\log_e \frac{4l}{d}$ is only 9·67.

The capacity area at the top affects the amount of energy that can be stored, but does not directly affect the rate at which it is emitted.

Given a spark half a centimetre long, representing a potential of, say, 12,000 volts, and given an aerial with $n = 10$, energy is emitted at the rate of

$$\frac{(12{,}000 \text{ volts})^2}{360n^2 \text{ ohms}} = \frac{4{,}000}{5} \text{ watts, or about horse-power.}$$

If we want an expression for the radiating power of an aerial of height h in terms of a considerable introduced coil-inductance L, it is as follows

$$\frac{\mu V^2 h^2}{3cL^2}, \quad \text{or} \quad \frac{V^2 h^2}{90(L/\mu)^2 \text{ ohms}}$$

If we express both h and L/μ in the same units, say, in metres, and V in volts, the answer will come out in watts as before.

Thus suppose $V = 12{,}000$ volts, $h = 10$ metres, and $L = \frac{1}{10}$ millihenry, so that $L/\mu = 1{,}000$ metres; the radiation power is $\frac{144 \times 10^6}{90 \times 10^4} = 160$ watts.

The expression for radiating power can be thrown into another form, and expressed in terms of the mean current flowing in the rod, without reference to sign; as measured, for instance, by a hot-wire instrument or an electrodynamometer. The radiating power of a dumb-bell oscillator—during its period of spark excitation—through the rod of which an average circuit of A amperes is flowing, is

$$800\frac{l^2}{\lambda^2}A^2 \text{ watts,}$$

where l is the mean distance between the terminal capacity areas and λ the wave-length.

For sustained oscillation of an effective current A amperes, in an aerial of height h, Dr. Eccles gives the radiating power as

$$640\frac{h^2}{\lambda^2}A^2 \text{ watts,}$$

showing that, for given current, the rate of energy emission is directly as the square of the height and inversely as the square of the wave-length.

Those who wish to follow out the whole process more in detail will find a summary of Hertz's equations in one of the concluding chapters of Preston's "Theory of Light." They will also find some of the facts clearly stated in Dr. Eccles's well-informed article "Wireless Telegraphy," in Vol. II of Glazebrook's "Dictionary of Physics," where the diagrams in Fig. 2 (page 2226) are quoted from Mr. Oliver Heaviside's mode of presentation.

In these figures the charges are seen oscillating up and down the vertical rod

A B, and the results, on electric lines of force connecting them, are followed through half a swing. In No. 1 the charges are separating by reason of their momentum. In No. 2 the charges have reached the ends of the rod and are reflected down again, as in No. 3. In No. 4 they are crossing in the middle; and in No. 6 they are at the ends again, but inverted. The Faraday lines joining them are like lines of longitude, and envelop the axis A B, though only one is shown. They expand outwards with the velocity of light, but by No. 3 they have begun branches going back to the middle, and in No. 5 they have begun to form two loops. In No. 6 the outer crescent-shaped loop has broken away, and thereafter pursues its course independently: the inner curve being an upgoing electric surge and the outer a downgoing one, so that the two together appeal to any receiving station as a half-wave.

A succession of such loops, flicked off and flying along with the velocity of light, constitutes the Hertzian waves which convey the signals. They very soon become practically expanding equidistant spheres, and at great distances are practically travelling planes. If the oscillator is halved by earth connexion at the middle, only the upper halves of these diagrams need be attended to.

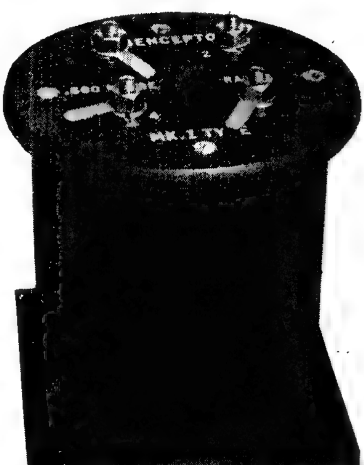
In these, and especially in the more complete diagrams, it is possible, with a little trouble, to visualize the flicking off of true waves at a certain distance from the oscillator, which subsequently expand in spheres, always advancing with the velocity of light; while near the oscillator it is possible to see the lines contorting themselves as the exciting charges move up and down, the energy for the most part pulsating and some of it returning to the oscillator, thereby tending to diminish the loss and prolong the swings.

When instead of a lower capacity area the earth is used as one end of the aerial, conditions become more indefinite and less amenable to calculation, and tuning cannot be quite so precise. For obviously the conducting power of the earth depends on the nature of the soil and on its state of moisture. If, however, it could be treated as a perfect conductor, the effect of the earth would be to reflect the aerial as a similar image, and to cut the field of radiation in half so that only the upper half of the wave diagrams are effective. The half loops then travel with their roots on the perfectly conducting surface. This may be approximated to on the sea; and it is again a question of compromise how far earth connexion is helpful and convenient in any given case. An earthed aerial seems more likely than an insulated one to collect stray disturbances—whether from natural causes or from heavy electrical engineering operations.

For early experiments on waves reference may be made to Proceedings of the Royal Society, vol. 50, page 1; and for further data about insulated aerials, to the same work, vol. 82, page 227.

WAVE TRAP. A device incorporated in a wireless receiving installation for eliminating interference from a transmitting station. The wave trap usually takes the form of a tunable inductance shunted across the aerial tuning inductance. In operation the wave-trap circuit is tuned to the exact wave-length of the interfering station, while the aerial tuning system of the receiver is carefully tuned to the wave-length of the station that it is required to receive. Many forms of wave traps of this description have two tunable circuits, so that interference from stations above and below the received wave-length may be eliminated.

A type of wave trap of commercial pattern is illustrated in Fig. 1, and requires a variable condenser for fine tuning. Of similar construction is the wave trap shown in Fig. 2. This instrument



LISSEN WAVE TRAP

Fig. 1. Type of wave trap for use on 600 metre range reception. No tuning element is used other than a ·0005 mfd. variable condenser

Courtesy Lissen, Ltd.

A B, and the results, on electric lines of force connecting them, are followed through half a swing. In No. 1 the charges are separating by reason of their momentum. In No. 2 the charges have reached the ends of the rod and are reflected down again, as in No. 3. In No. 4 they are crossing in the middle; and in No. 6 they are at the ends again, but inverted. The Faraday lines joining them are like lines of longitude, and envelop the axis A B, though only one is shown. They expand outwards with the velocity of light, but by No. 3 they have begun branches going back to the middle, and in No. 5 they have begun to form two loops. In No. 6 the outer crescent-shaped loop has broken away, and thereafter pursues its course independently: the inner curve being an upgoing electric surge and the outer a downgoing one, so that the two together appeal to any receiving station as a half-wave.

A succession of such loops, flicked off and flying along with the velocity of light, constitutes the Hertzian waves which convey the signals. They very soon become practically expanding equidistant spheres, and at great distances are practically travelling planes. If the oscillator is halved by earth connexion at the middle, only the upper halves of these diagrams need be attended to.

In these, and especially in the more complete diagrams, it is possible, with a little trouble, to visualize the flicking off of true waves at a certain distance from the oscillator, which subsequently expand in spheres, always advancing with the velocity of light; while near the oscillator it is possible to see the lines contorting themselves as the exciting charges move up and down, the energy for the most part pulsating and some of it returning to the oscillator, thereby tending to diminish the loss and prolong the swings.

When instead of a lower capacity area the earth is used as one end of the aerial, conditions become more indefinite and less amenable to calculation, and tuning cannot be quite so precise. For obviously the conducting power of the earth depends on the nature of the soil and on its state of moisture. If, however, it could be treated as a perfect conductor, the effect of the earth would be to reflect the aerial as a similar image, and to cut the field of radiation in half; so that only the upper half of the wave diagrams are effective. The half loops then travel with their roots on the perfectly conducting surface. This may be approximated to on the sea; and it is again a question of compromise how far earth connexion is helpful and convenient in any given case. An earthed aerial seems more likely than an insulated one to collect stray disturbances—whether from natural causes or from heavy electrical engineering operations.

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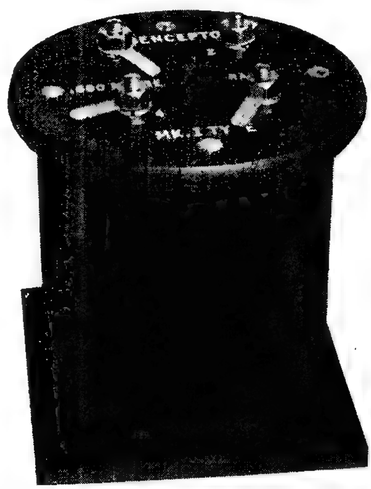
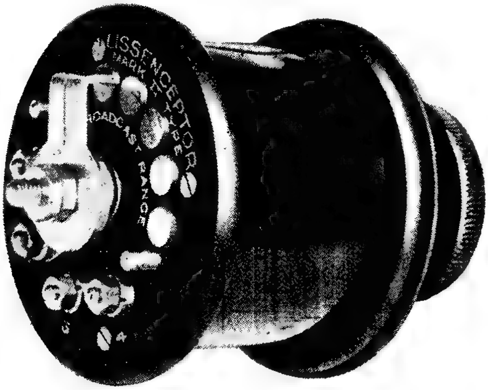


LISSEN WAVE TRAP

Fig. 1. Type of wave trap for use on 600 metre range reception. No tuning element is used other than a ·0005 mfd. variable condenser

Courtesy Lissen, Ltd.



COMMERCIAL TYPE OF WAVE TRAP

Fig. 2. This type by the same manufacturers as the example in Fig. 1 is more closely regulated by the five-stud switch

Courtesy Lissen, Ltd.

incorporates a five-stud switch, and can be more closely regulated than the other type illustrated. *See* Interference Eliminator.

WAX. A semi-solid, paste-like material. Waxes used in wireless work are those

Fig. 2

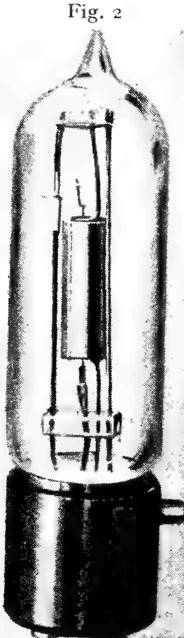
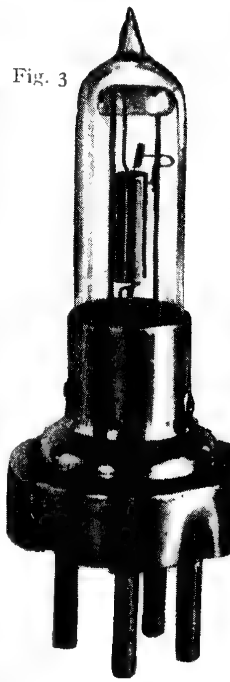
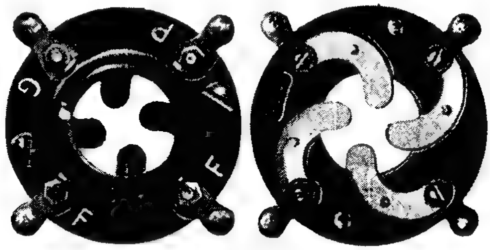


Fig. 3



possessing good insulating properties, and the chief of these is perhaps paraffin wax. This is extensively used for impregnating paper and other materials in the construction of dielectrics for small condensers, and also for filling holes or channels containing conductors.

A variety of other wax-like compositions are made up, comprising resin, shellac, beeswax and the like, often with the addition of pitch, tar and bitumen,



WECO VALVE HOLDERS

Fig. 1. This holder, used with Weco valves, is constructed to minimise inter-electrode capacity effects. Notice the marking of the electrodes, the two filament leads being together

these possessing insulating qualities, and also to a large extent being moisture-proof. They are prepared in various ways,

Fig. 4

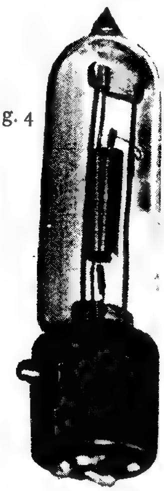
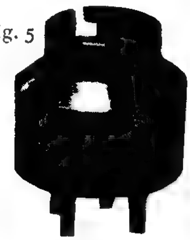


Fig. 5



WECO VALVES

Fig. 2. Western Electric Co.'s type, which operates on ·8 to 1·1 volts and ·25 ampere for the filament and 17-45 volts for the anode. Fig. 3. Mullard Weco valve. Fig. 4. "Peanut" type of Mullard Weco valve. Fig. 5. Four-prong adaptor for "Peanut" Weco valve

a typical example being the braided covering for an insulated conductor. *See* Basket Coil; Coil.

WEBER. Name given to the unit of magnetic flux. It is the flux produced by a current of one ampere flowing through a circuit with one henry inductance. The name Weber has been largely superseded by the term Maxwell (*q.v.*).

WECO VALVE. A special small thermionic valve introduced by the Western Electric Co. It is virtually an ordinary thermionic valve, but operates at ·8 to 1·1 volts and ·25 ampere for the filament, and 17 to 45 volts for the anode. It

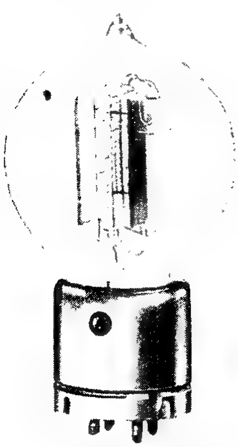
measures about $2\frac{1}{2}$ in. in length and $\frac{5}{8}$ in. in diameter. It is admirably adapted for all classes of amateur wireless reception, particularly when the apparatus is required to occupy a small space, and has advantages when dry battery operation is desired. Several types of this well-known valve are illustrated in the previous page, and along with these are shown the adaptors specially made for use with them. *See* Valves for Reception.

WEHNELT ELECTRODE. Name generally given to a type of electrode in valves, due to A. Wehnelt. Wehnelt discovered that the current-carrying capacity of a wireless valve was increased by coating the filaments with calcium oxide. *See* Dull Emitter Valves.

WELDING. Method of uniting ferrous metals. Welding is adapted in wireless work chiefly in the fashioning of iron or steel parts for aerial masts and other constructive work.

WESTERN ELECTRIC. Abbreviated title of the Western Electric Company, Ltd., one of the leading manufacturers of electrical and wireless apparatus. An example of the thermionic valve manufactured by this firm is illustrated in Fig. 1, and is known as the L.S.2 valve. The arrangement of the plate and grid should be noted. Another well-known valve made by the same firm is the Weco (*q.v.*).

An adaptation of this small dry-battery valve in the form of a two-stage amplifier for a crystal set is illustrated in Fig. 2. This amplifier is adapted to slip into the telephone compartment in the standard Western Electric Co.'s crystal receiving set. A three-valve two-stage amplifier is illustrated in Fig. 3. In this case three Weco valves are used, and connexions are made in such a way that the amplified current produced by one valve is collectively dealt with by the other two.

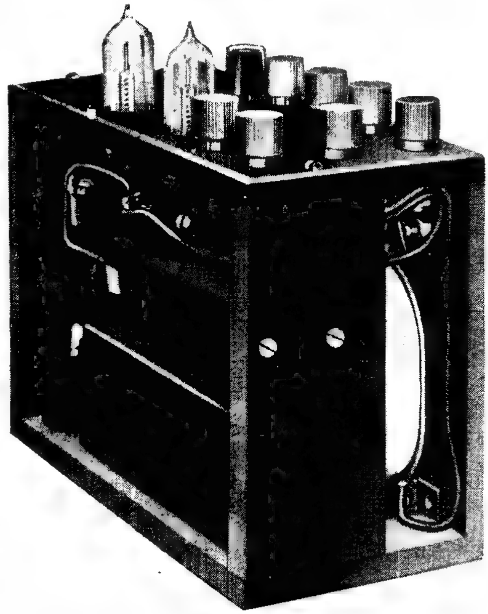


WESTERN ELECTRIC L.S.2 VALVE

Fig. 1. This valve is remarkable for the shape of the anode and grid and also the structure of the valve legs

WESTON CELL. Type of cell adopted by scientists as the standard of electromotive force, on the recommendation of the International Conference of Electrical Standards held in London in 1908.

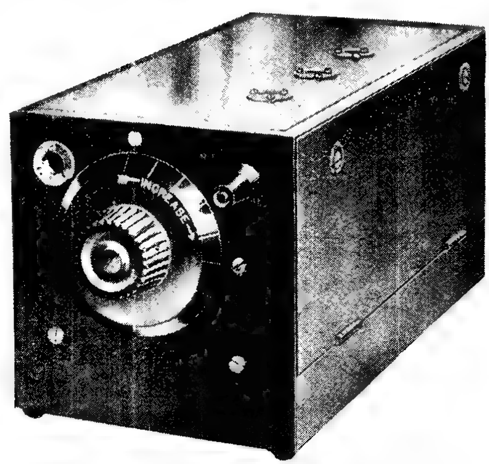
Fig. 1 shows the external construction of a standard type of Weston cell. It will be seen that the whole instrument is totally enclosed within a cylindrical brass



TWO-STAGE L.F. AMPLIFIER FOR CRYSTAL SET

Fig. 2. In this amplifier Weco valves are used. The instrument fits the telephone compartment of the Western Electric Co.'s receiver

Courtesy Western Electric Co., Ltd.



TWO-STAGE AMPLIFIER FOR VALVE SET

Fig. 3. Three Weco valves are used in this set, which is a two-stage amplifier

Courtesy Western Electric Co., Ltd.

WESTON STANDARD CELL

Fig. 1. This cell has been adopted by scientists as the standard cell with which comparisons with other cells are made

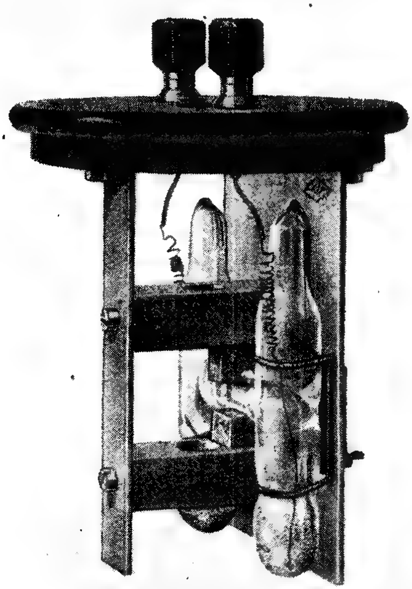
Courtesy Cambridge and Paul Instrument Co., Ltd.

casing having an ebonite top-plate. The latter is fitted, in this instance, with four terminals, as there are two cells enclosed, one being used as a check against the other. In the centre of the top, also, is a small hole through which a thermometer may be placed in order that an accurate check on the internal temperature may be taken. This is a most important point, for the voltage depends to some extent upon the temperature.

The interior of a single Weston cell may be seen by reference to Fig. 2. Upon a stamped metal framework attached to the underside of the ebonite top is a hermetically sealed glass vessel, the shape of which approximates to the letter H. One of the vertical limbs of this tube contains in its lower portion a quantity of mercury. The latter is covered first by a layer of mercurous sulphate, and secondly by a layer of cadmium sulphate crystals. In the opposite limb is a small quantity of cadmium amalgam covered with cadmium sulphate crystals. Both of these tubes have a constriction formed at the level of the top of their solid contents, so that the upper layers of cadmium sulphate crystals form a kind of taper plug, which holds the contents in place.

The rest of the interior of the tube, up to the level of the horizontal limb, is filled with a saturated solution of cadmium sulphate. Silk cord lashing is used to secure the tube to the metal frame, and connexions to the terminals are taken from two leads of platinum sealed into the glass tubes near the bottom. The Weston cell gives an E.M.F. of 1·0184 volts at a temperature of 20° C. *See* Primary Cell.

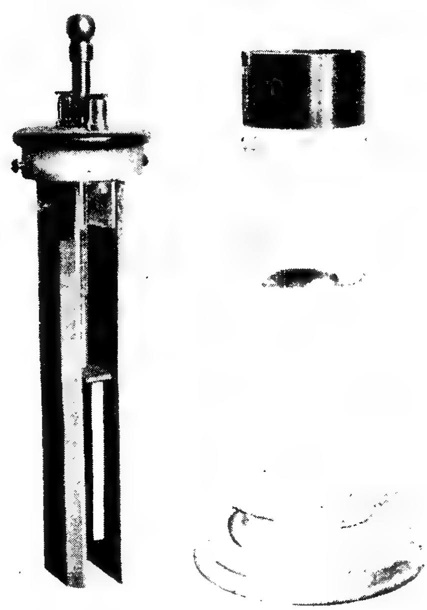
WET CELL. General name given to those primary cells in which the electrolyte is a fluid, in contradistinction to the dry cell, in which the electrolyte is in the form of a paste. The figures show the component parts of two well-known forms of wet cell. Fig. 2 shows the positive



INTERIOR OF WESTON CELL

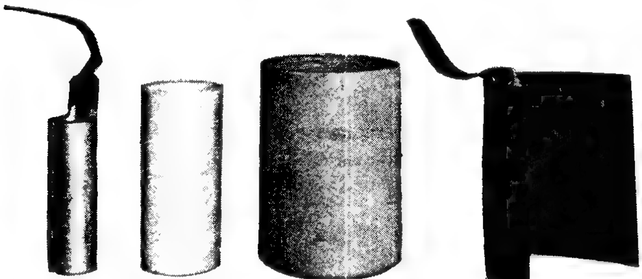
Fig. 2. Interior of the single cell, showing the curious H-shaped hermetically sealed glass vessel attached to the stamped metal framework

Courtesy Cambridge and Paul Instrument Co., Ltd.



ORDINARY WET CELL

Fig. 1. Here is shown the glass containing vessel and the two elements of standard bichromate cell. This cell is economical in use provided the plate is withdrawn when not in use



DANIELL CELL COMPONENTS

Fig. 2. On the outside are the two electrodes of the cell. The porous pot and the glass container shown in the centre complete the cell

and negative electrodes of an ordinary Daniell cell on the extreme right and left of the photograph, the glass containing jar and the porous pot which is a feature of this type of cell.

Fig. 1 shows the glass container and the two elements of a bichromate cell. This type of cell is fully described under the heading Bichromate Cell, and full particulars are given under the heading Bichromate Battery of how to make one. *See* Primary Cell; Dry Cell.

WHEATSTONE, SIR CHARLES (1802–75), British physicist. Born in February, 1802, at Gloucester, he was educated at private schools, and on leaving carried out privately many experiments in acoustics under the aegis of his father and uncle, a musical instrument maker. After some years' study of acoustics he devoted himself to experimental research of various kinds, and wrote a number of papers for scientific societies.

In 1834 he was appointed professor of experimental philosophy at King's College, London. Here he demonstrated a method of determining by means of a revolving mirror the speed of an electric current, a highly important investigation which led ultimately to the invention of the electric telegraph. Wheatstone obtained the co-operation of W. F. Cooke, and the two brought out in 1837 a patent for an electric telegraph. He invented the A B C instrument, the automatic transmitter and receivers, and many forms of electrical apparatus. He has rightly been called the father of modern telegraphy, and it is due to his genius and investigations that modern telegraphy has become the best-known method of communication throughout the world.

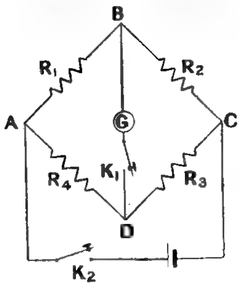
Wheatstone carried out many researches in sound and light as well as electricity. He investigated the speed of sound through solids, gave an explanation of Chladni's figures of vibrating solids, and invented the concertina, stereoscope, the polar clock, electrical chronoscopes and a ciphering and deciphering machine, among other things.

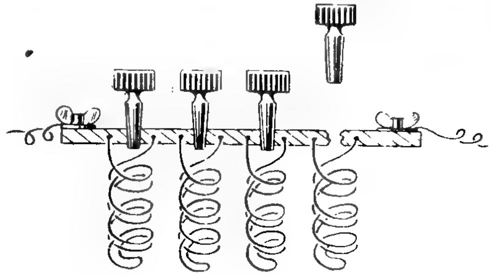
Sir Charles Wheatstone has also been credited with the invention of the Wheatstone bridge, but the device was actually invented by Christie, though Sir Charles made considerable use of the invention. He was made a fellow of the Royal Society in 1837, and knighted in 1868. He died in Paris on October 19th, 1875.

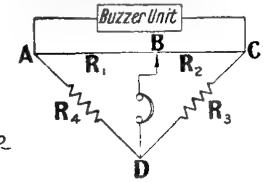
WHEATSTONE BRIDGE. Device for measuring an unknown resistance by means of a known resistance. It consists of a network of six conductors joining four points, and was invented by S. H. Christie, of the Royal Military Academy at Woolwich. Sir Charles Wheatstone pointed out the immense importance of the arrangement to electricians, and the device has come gradually to bear his name, though he gave the credit to Christie.

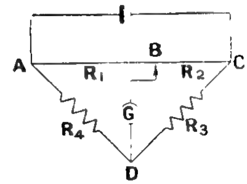
Fig. 1 shows the circuit diagram of the usual form of Wheatstone bridge. R_1, R_2, R_3 and R_4 are four resistances joined as shown at the points A, B, C, D. From B to D is a conducting path which can be opened or closed by a key, K_1, and which has a galvanometer in it. From A to C there is a conducting path with a battery key, K_2.

Suppose the key K_1 is open and the key K_2 is closed. Then a current from the battery will divide at A, part of it going along A B C and part of it along A D C. There will be a fall of potential from A to C, but since in the two branches A B C and A D C the fall is the same from A to the point C, there will be a point in A D C at which the potential is the same as that of a selected point in A B C. Suppose the point B is selected in A B C, and suppose the potential at some point D in A D C is the same as that at B. Then if the points B and D are joined by a conductor in which there is a galvanometer, no current flow will be indicated, the pointer of the galvanometer not deflecting.









CONSTRUCTION AND THEORY OF WHEATSTONE BRIDGE

Fig. 1 (left). Circuit diagram of common Wheatstone bridge. Fig. 2 (centre). How plugs and resistance wires are used in the Post Office type. Fig. 3 (lower, right). Modification known as the slide-wire bridge. Fig. 4 (top, right). Adaptation to wireless A.C.

Now the differences of potential between A and B and between A and D are the same, since B and D are at the same potential; and the differences of potential between B and C and D and C are the same. So we can write down the following equations:—

P.D. between A and B = P.D. between A and D, and P.D. between B and C = P.D. between D and C.

If C_1, C_2, C_3, C_4 are the currents in R_1, R_2, R_3, R_4 respectively, we can write these two equations down as

$$C_1R_1 = C_4R_4$$
$$C_2R_2 = C_3R_3$$

or, dividing one equation by the other,

$$\frac{C_1R_1}{C_2R_2} = \frac{C_4R_4}{C_3R_3}$$

But the current in A B, *i.e.* C_1, is equal to the current in B C, *i.e.* C_2; and the current in A D, C_4, equals that in D C, C_3, so that the equation becomes

$$\frac{R_1}{R_2} = \frac{R_4}{R_3}$$

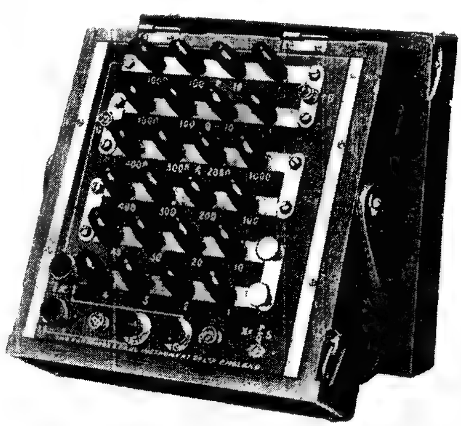
From this equation it is clear that if the resistances of three of the arms of the bridge are known, the resistance of the fourth may easily be calculated, or if the resistance of one conductor adjacent to the unknown resistance is known, and the ratio of the other two resistances is known, the unknown resistance can be found. The resistances R_1, R_2, R_3, R_4 are generally known as the arms of the bridge and D B as the bridge wire.

It is usual in practice to have the two resistances R_1, R_2, called the ratio arms, fixed and in a decimal ratio to one another, *e.g.* 1,000 ohms to one ohm, or 10,000 ohms to 100 ohms, and so on, while the resistance, R_3, the measuring arm, is variable, and R_4 is the resistance to be measured.

The unknown resistance is inserted in the circuit, and R_3 varied until the galvanometer reading is zero, when R_4 can be calculated.

A common form of Wheatstone bridge is that known as the Post Office pattern, shown in Fig. 5. In this well-known pattern there are a number of coils of known resistance arranged so as to form three arms of the Wheatstone bridge. The ends of the coils are fastened to solid brass blocks separated from each other, a portion of each gap having a circular conical hole made in it, into which conical brass plugs can be inserted. Fig. 2 will make this internal construction clear.

When a plug is inserted it is clear that that particular resistance coil is cut out of the circuit, the current passing from one brass block to the next through the plug, so that the removal of a plug increases



POST OFFICE PATTERN

Fig. 5. This is the most common type of Wheatstone bridge. The plugs when taken out increase the total resistance

Courtesy Cambridge and Paul Instrument Co., Ltd.

the resistance of the circuit. The coils, it will be noticed, are non-inductively wound. The top of the box is of ebonite and the brass plugs have ebonite tops. In Fig. 2 the ratio arms consist of eight coils having resistances of 1, 10, 100 and 1,000 ohms, while the measuring arm consists of sixteen coils with resistances of 1, 2, 3, 4; 10, 20, 30, 40; 100, 200 300, 400; 1,000, 2,000, 3,000 and 4,000 ohms, so that with all the plugs withdrawn there is a total resistance of 11,110 ohms in this series of coils. By withdrawing two plugs in the ratio arms any decimal ratio from 1,000 to 1 and 1 to 1,000 may be obtained.

On the left of where the ratio joins the measuring arm is the galvanometer terminal, on the right the battery terminal, and below the resistance terminals for the insertion of the unknown resistance.

Fig. 3 shows another arrangement of the Wheatstone bridge, often known as the slide-wire bridge. Here a uniform resistance wire A B C has a sliding contact, B, connected to the galvanometer. The circuit is identical with that shown in Fig. 1, and has been lettered in a corresponding way. By sliding the contact B along the wire we can obtain the balance when no current passes through G, and we get, as before, $R_1/R_2 = R_4/R_3$. The ratio R_1 to R_2 is the same as the ratio of the lengths of A B to A C, so that if A B has a divided scale attached to it and R_3 is known, R_4 may be found.

Wheatstone Bridge for Wireless

In wireless alternating currents are used and the forms of Wheatstone bridge already described could not be used, but the bridge is very easily adapted, as shown in Fig. 4. Here the battery is replaced by a buzzer, which gives an alternating current through the arms of the bridge and the galvanometer by a telephone. The sliding contact, B, is adjusted until a minimum sound is heard in the telephones, and the unknown resistance is found from the same equations as hold good for Fig. 3.

Instead of the resistances R_4 and R_3, an inductance coil of unknown value, X, may replace R_4 and a coil of known inductance, L, replace R_3 in Fig. 4. When the slider is moved until there is a minimum sound in the telephones we have the equation

$$X/L = R_1/R_2$$

The unknown inductance should be of the same order of magnitude as that of the known, or otherwise it will not be possible in practice to obtain a balance. This result is not precise, for the obvious reason that it neglects the resistances of the inductances, but it is sufficiently accurate for most amateur work. In page 1161 is described a more accurate form of the bridge, together with the necessary formulae for obtaining the inductance of a coil from bridge measurements. Fig. 6 shows a method which may be used by the amateur to take account of the resistances. In the arm in which are connected the inductance coils are inserted variable non-inductive resistances whose values are known.

Obtaining a Balance

By throwing the buzzer battery switch over to the right, the bridge may be balanced for resistances using the galvanometer to indicate the position of balance. By throwing both switches over to the left the circuit is used to balance for resistances for alternating current, the buzzer and telephones being used in the way already explained. The following is the actual method of procedure.

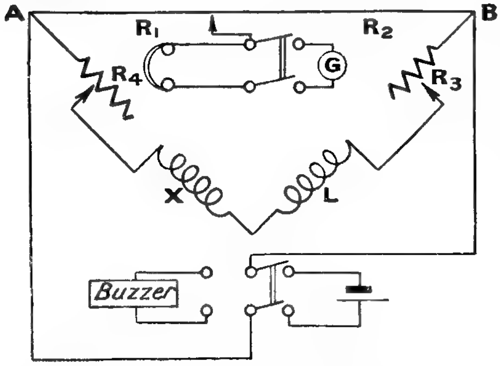
The throw-over switches are thrown to bring the telephones and buzzer into circuit and the sliding contact adjusted for minimum sound in the telephones.

The switches are now thrown to bring the galvanometer and battery into circuit and the resistances R_3 and R_4 varied, keeping the slider in the position already obtained until the galvanometer does not deflect. Throw over the two switches again and move the slider until minimum sound is heard in the telephones. Again switch the battery and galvanometer into circuit and vary R_3 and R_4 until a balance is obtained with the slider in the new position. This procedure should be carried out until there is no deflection in the galvanometer on switching it in and a minimum noise in the telephones when the buzzer is used. The equation

$$X/L = R_1/R_2$$

then applies.

Capacities may be measured by using the circuit shown in Fig. 4, the unknown capacity replacing R_4 and a known capacity replacing R_3. If in place of R_3 a variable air condenser is used and the slider is set at the mid point of A C, then the capacity of the condenser is varied until the minimum sound is heard in the telephones. The reading of the condenser gives that of the unknown capacity approximately.



MODIFIED WHEATSTONE BRIDGE

Fig. 6. By means of this form of circuit the inductance value of a coil may be accurately determined

The construction of the Wheatstone bridge shown in Figs. 3, 4 and 6 is a simple matter, and will enable the amateur to get a close approximation to the values of the various components he may be using in his set. The uniform resistance wire may be of any standard material, as manganin. It should be connected to large terminals mounted on an ebonite panel. Underneath should be fixed a scale, preferably a centimetre scale. A convenient length for this scale and the wire is 100 centimetres, and the gauge of the wire may be about No. 20. The connexions to the terminals should be absolutely electrically sound, and the two connexion points should be on each terminal to connect up to the buzzer or battery. If the connexions are not sound there will be an increase in resistance of unknown amount, and the accuracy of the bridge will be lost.

The slider may be simply made with a small telephone clip to which has been soldered a length of flexible insulated wire. Before the wire is finally fixed in position the terminal should be clipped on to it. A firm connexion is made by screwing down the terminal screw in the usual way, releasing it when sliding the terminal along the wire. The ordinary dry cell will do for the battery, and small buzzer sets may be bought, or one made as described in this Encyclopedia under the heading Buzzer. An ordinary pair of headphones may be used. For a standard inductance a honeycomb coil may be used whose inductance is given by the makers. Precision condensers, such as those made by the Sterling Telephone Co., may be used when testing the capacities of unknown condensers. *See* Anderson Bridge; Bolometer Bridge; Capacity; De Sauty Bridge; Foster Bridge; Inductance; Resistance; Resistance Box.

WHEATSTONE TRANSMITTER. A mechanical automatic device operated by a punched tape for transmission at high speed. *See* High-speed Transmission.

WHIDDINGTON, RICHARD. British physicist. Born in London, November 25th, 1885, he was educated at St. John's College, Cambridge, and carried out research work at the Cavendish laboratory under Sir J. J. Thomson. In 1911 he was elected a fellow of St. John's College, and during the Great War he designed a number of the standard R.A.F. wireless sets used on aeroplanes and in aircraft work generally. After the Great War he was appointed professor of physics at Leeds University, and a member of sub-committee D, on thermionic valves, of the Radio Research Board. Professor Whiddington has written many important papers on electrical subjects.

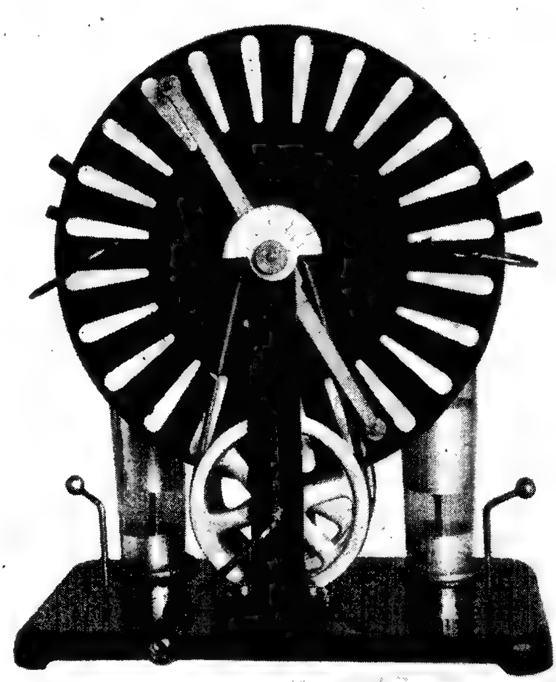
WHIPPING. Word used in two senses in wireless work. In one application it refers to the bending or displacement of a rod or shaft while under load, an example being the bowing of an aerial mast or the bending of a rotating shaft such as that of an armature. In another sense, whipping consists of a kind of binding of twine, string or wire around a stranded wire or cable for the purpose of preventing the ends from fraying out. *See* Seizing.

WHISTLING. Sound heard in the telephones of a receiving set. Whistling may be caused by the reaction coil being too tightly coupled, and this is one of the chief causes. The sound will generally cease if the coil is more loosely coupled. Whistling noises may also be caused through a receiving set in the neighbourhood oscillating, in which case there is no remedy until the offender stops. Bad connexions, too high a plate or filament voltage, body capacity, etc., are all also causes of whistling. *See* Howling.

WIEN, MAX. German wireless authority. Born at Konigsberg in 1866, he studied physics under the famous Helmholtz, and eagerly followed up the experiments of Hertz. In 1891 he worked with Röntgen, and then turned his attention to the study of wireless waves. In 1906 he published the results of his researches on the properties of short spark gaps, which resulted in a great advance in the

improvement of spark gaps for rapid discharges, since the discharge across such spark gaps is very rapidly quenched out after a few oscillations. Wien's discovery is generally known as the quenched spark gap.

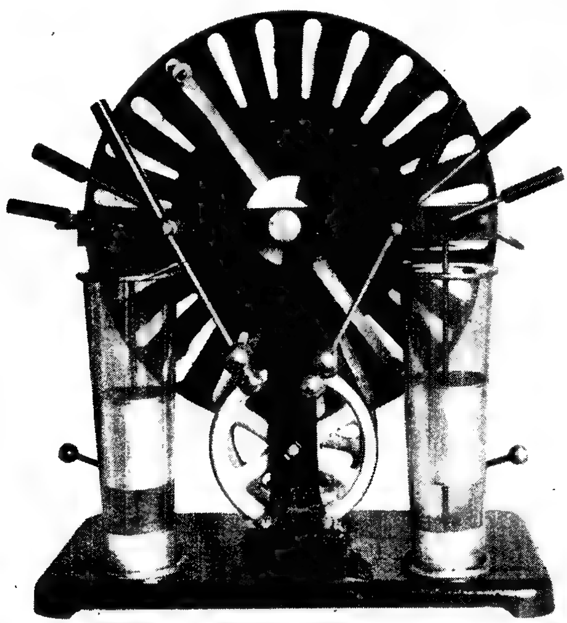
Professor Wien studied how special forms of Geissler tubes could be used in series with an ordinary spark gap so that their resistance rapidly damps out the discharge. He designed several forms of these quenching tubes, capable of handling very heavy condenser discharges without overheating. Professor Wien has written many articles and published many papers on the theory and practice of quenched spark gaps.



WIMSHURST MACHINE

Fig. 1. View of the machine from the driving side, showing clearly details of the collecting arms and the Leyden jars

WIMSHURST MACHINE. Name given to a particular type of apparatus employed for experimental purposes in connexion with static electricity. Essentially, the instrument consists of two insulated plates set on a common spindle and capable of revolving at high speeds in opposite directions. Around the circumference of the plates a number of segments of tinfoil are pasted. The current induced between the opposing sections in opposite segments is picked up by means of metallic arms fitted with soft brush contacts.



REAR VIEW OF THE MACHINE

Fig. 2. This photograph gives a clear view of the variable spark gap fitted with insulated handles, which enables the length of the spark to be regulated while the machine is being operated

Two or more Leyden jars are usually incorporated to give intensity to the spark. A typical two-plate Wimshurst machine viewed from the driving side is illustrated in Fig. 1, this illustration clearly showing the collecting arm and the Leyden jars. A rear view of the same instrument is shown in Fig. 2, and this shows the variable spark gap fitted with insulated handles, so that the length of the spark may be regulated while the machine is in operation.

WINDINGS. General term for the turns of wire used on many forms of wireless apparatus. Thus the turns of wire round a transformer are often spoken of as primary and secondary windings; in a variometer as the rotor and stator windings; in an electro-magnet as pole windings, etc.

WINDOW INSULATOR. A particular form of lead-in insulator. In the Burndept pattern illustrated the insulator is

WINDOW INSULATOR
Two ebonite rods, each having a disk bound with rubber, are used in this insulator, which is used to bring the lead-in wire through a window-pane
Courtesy Burndept, Ltd.

composed of two ebonite rods, each having a disk attached, faced with rubber. A ¼ in. diameter brass bar passes through the centre and terminates at either end with lock nuts and terminals. In use, a small hole is drilled through the glass of the window pane, the brass bar removed from the insulator, passed through this hole, and one of the ebonite rods placed at either side of the window, the whole being held tight by screwing up the lock nuts. *See* Aerial; Bradfield Insulator; Lead-In.

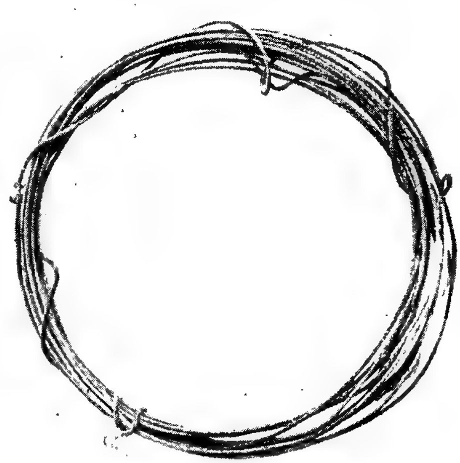
WIRE. In wireless work many forms of wire are employed. The aerial is usually made of multi-stranded wire consisting of several strands of copper, bronze, or sometimes steel. This is connected to the set by insulated wire, which may be single or multi-strand, and covered with an insulation consisting of cotton or similar material impregnated with an insulating compound. In the set much of the coil winding is carried out with cotton or silk-covered tinned copper wire. Alternatively enamelled copper wire may be used. The internal connexions are often made with bare tinned copper wire square in section. For other purposes a flexible wire is better, and is imperative for connexions between parts that are movable relatively to one another. Flexible wire is usually composed of a great number of thin strands of copper wire covered with insulation.

Several special forms of wire are utilized for specific purposes, such as Litzendraht. Wire used for the support of an aerial mast, or for other power purposes, is generally of stranded steel or galvanized iron. An example is illustrated.

Wire is generally sold by gauge numbers. The Imperial standard wire gauge is the legal gauge in Great Britain. Each size differs by a few thousandths of an inch in diameter only, thus offering wide choice of size. Details of the various sizes, numbers of turns per inch, and other information should be found from the regular wire tables, selections from which are to be found under their respective headings in this Encyclopedia.

The term wire is also applied to a number of variously sectioned strips of metal, such as half-round, oval, flats and pinion, all of which are available for amateur constructional purposes. *See* Gauge; Imperial Wire Gauge.

WIRED WIRELESS. Name applied to a system of transmitting telegraph signals or telephony over wires by using high-frequency currents and employing wireless methods in transmission and reception. Ordinary radio transmission uses oscillatory currents which may be allied to the usual single-phase currents used for power work, except that they are of a much higher frequency. Because of this high frequency, conditions obtaining in ordinary circuits which are of no importance in the lower frequencies assume definite importance and have effect on the currents travelling through them, and by suitably designing the circuits it is possible to radiate into free space a certain proportion of the current. It is due to this fact



GALVANIZED WIRE
Galvanized wire is very useful to the wireless experimenter for the staying of aerial masts and such similar purposes

that wireless communication becomes a possibility. It is therefore conceivable that by arranging the circuit so that only the smallest possible radiation obtains, the transmission of high-frequency current over wires may be effected.

The simplest and best method of obtaining this effect is by connecting the output of the transmitting apparatus to two parallel conductors, and it has been proved that under these conditions the radiation will be very small, with resultant small losses in the transmitted currents. It is important to note that the actual conduction of the currents still takes place in the ether surrounding the wires, rather than in the wires themselves, the latter acting as a kind of guiding medium.

Duplex Wired Wireless

Experiment has proved that high-frequency currents may be transmitted over wires carrying either direct current or alternating currents of lower frequencies without one affecting the other, and, further, that more than one series of high frequencies may be carried along the same wires without interference, providing that they vary in frequency to a sufficiently large extent.

From the above it is apparent that wired wireless offers advantages over ordinary low-frequency line communication in that "duplexing" is possible by working both a high- and low-frequency conversation along it. Apart from that, owing to the aptitude of high-frequency currents for passing through conditions in a circuit which present an almost infinite impedance to currents of a low frequency, it is possible to convey them to the line through such mediums as a very weak magnetic coupling or a very small capacity. Thus such connexions may be made with safety even on lines through which enormous electrical powers are being conveyed, always providing that the insulation on the connecting medium is sufficient to oppose the voltage of the ordinary line current.

All types of line do not offer the same advantages to the carrying of high-frequency currents. For instance, iron wires present almost insuperable difficulties owing to the losses due to hysteresis, and underground cables are unsuitable owing to the large amount of capacity present. Obviously, therefore, copper conductors carried overhead offer the greatest advantages, although the actual ohmic resistance is of little importance. As regards the power required, this is very small compared with radio working, and under favourable conditions, and with suitable lines, distances of several hundred miles may be traversed successfully with a power of only 20 watts.

Power lines are, on the whole, to be preferred to ordinary overhead telephone lines, because they are of low resistance, highly insulated, and do not as a rule vary in constants—as, for instance, by sudden changes from overhead to underground and vice versa.

Again, a disconnexion in a line carrying high-frequency currents does not always mean complete cutting of communication, for radiation and induction will sometimes bridge the gap and still allow communication, but with a lowered efficiency. In this connexion it is interesting to state that during the course of some tests in England over telephone lines running parallel to 10,000 and 20,000 volt power lines, continuity of conversation was obtained without any apparent loss of efficiency, despite the fact that one of the telephone lines was completely broken and lying on the ground for some 170 yards. So little difference did this make to the conversation that the experimenters did not notice the event until it was pointed out to them.

Interference not a Serious Matter

Referring again to the possibilities of transmitting more than one frequency of oscillations along the same wire, we must consider to what extent this may be done. In the first place all the advantages in wireless of tuning may be used as a means of providing selectivity; it is therefore easy to see that interference between frequencies is not a serious factor, but at the same time there are definite limits to the number of frequencies which may be simultaneously applied.

In the first place the human ear cannot generally hear sounds above 20,000 cycles per second, any sounds immediately below that frequency being heard as a very high squeak, so that the lowest limit of frequency which may be used is represented by that figure. Again, owing to the well-known beat or heterodyne principle, it is obvious that all frequencies above that of the lowest must be so far above that they do not combine and produce any beat

note of less than 20,000. . Therefore the frequencies must be separated by at least 20,000 cycles per second, and thus if the first were 20,000 the next would be 40,000, and the next 60,000, etc. Unfortunately it is impossible to carry the frequency to too high an extent, for the use of very high frequencies results in serious losses through attenuation along the line.

So far, we have considered only that portion of the transmission which represents the carrier wave.

The impression of the modulated frequency upon this is to further complicate matters, for the effect of the speech and music frequencies is to produce others, and in the case of wired wireless the best conditions obtain for interference between these frequencies, for all are more or less similar in intensity. Again, harmonics of the carrier waves may easily become serious causes of interference.

Where simultaneous working between several stations is in progress, this interference may only be avoided by the use of filter circuits specially designed for the individual circumstance, and these may be applied either between transmitter and line or line and receiver.

As far as the design of the stations is concerned, these will be purely standard wireless sets of suitable power and employing valves, but they must be designed to work on the duplex system. The transmitter will consist of a small motor-generator for high-tension supply with suitable smoothing circuits, the usual valve oscillator and modulator circuits, batteries and a telephone attachment, for direct or remote control.

Calling-up Devices Employed

Before conversation may be effected the user must naturally start up his apparatus and generate the high-frequency oscillations. In order to obviate the necessity for the receiving valves to be always supplied with current ready for any call, it is necessary to use some form of calling-up device. For this purpose the Marconi Co. have developed an electro capillary tube operating in conjunction with a carborundum crystal. This tube is mounted upon the beam of a most sensitive balance, which, when supplied with minute rectified high-frequency currents through the crystal detector, trips, and in so doing closes a pair of contacts connected in a local bell circuit. The receiving operator then may lift his telephone receiver off the hook, and the two stations are in conversation.

Some complications ensue, however, on the system being extended to more than one station. For example, take a scheme employing four stations, A, B, C and D, where each must be capable of calling and speaking with any other. This installation might well apply to any power supply scheme, where, say, station A might belong to the chief engineer's office, and the others to assistant engineers in sub-stations any number of miles away.

Quadruplex Conversations

Under these conditions each station would be given a fixed receiving wave-length, say λa, λb, λc, λd, but each station must be capable of transmitting on any of the wave-lengths, so that station B, for instance, may transmit on λa, λc and λd.

Let us now assume that A wishes to speak to C. The first step A makes is to adjust his transmitter to λc, start up, and thus call C. Upon C hearing the call, he cannot immediately start up both transmitter and receiver, for he does not yet know with whom he is in communication. He therefore uses his receiver only until he knows who is calling him, and upon ascertaining that he adjusts his transmitter to λa. Both stations are then ready for conversation.

If during this conversation another station B, for instance—wishes to speak to A (not knowing that the latter is engaged) and starts his transmitter, jamming would be caused. B must therefore first use his receiver, and adjusting it to λa, would hear C speaking on it.

On paper this system would appear to have many limitations and drawbacks, but in actual practice, on lines where privacy is not essential and all operators are conversant with the general outlines of wireless methods, inter-communication may be carried on with reasonable facility and greater certainty than with an ordinary telephone system.

So far, we have only discussed wired wireless as applied to small private systems, but it has a very much larger field of utility than this. In some countries, notably America, whole electric light and power installations for public supply have been impressed with high-frequency currents operated by powerful transmitters

and conveying speech and music in the form of entertainment. Under such a scheme any consumer of the company's electricity might at any time have the entertainment provided by merely attaching a wireless receiver to the mains by means of either a condenser such as the "Ducon" (*q.v.*) or a form of loose magnetic coupling.

In countries where power lines are carried overhead such a scheme is suitable, but in countries where practice specifies underground systems, the large difficulties obtaining through the capacity of lines renders the successful application of wired wireless for entertainment practically impossible.—*R. B. Hurton.*

See Broadcasting ; Transmission.

WIRING: THE BEST METHODS FOR SUCCESSFUL RESULTS

How to Carry Out an Operation of Great Importance; Fully Illustrated

In the subjoined article is given a full description of the various methods of wiring a wireless set—an operation upon which depends the greater part of the success of amateur sets. The reader should refer also to the various headings dealing with set construction, and to such headings as Coils, Soldering, etc.

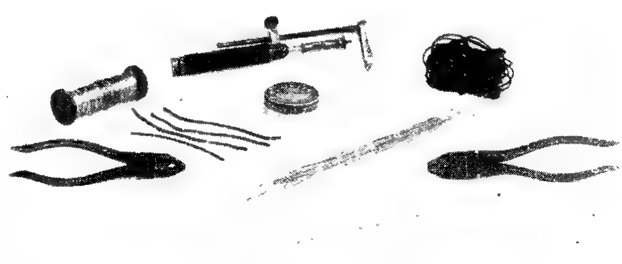
Wiring is an expression applied to the process involved in effecting the whole of the connexions in and to a wireless transmitting or receiving set. Provided the components are themselves of the correct value and correctly disposed on the panel and elsewhere, and should reasonably be expected to function in the proper manner, the whole of the success of the average amateur receiving set depends upon the care with which the wiring operations are performed.

In this Encyclopedia detailed instructions have been given for the construction of the various types of receiving and transmitting sets, and a large number of different circuit diagrams have been provided. The following notes apply in general to all classes of wireless apparatus. Naturally, some are more difficult to wire than others. This may not be due entirely to the complexity of the circuit itself, but is more generally the result of indifferent planning when arranging the rotation of the various components, or is necessarily the result of attempting to work the set into the minimum possible space.

An ideal arrangement for wiring is one in which the components are mounted on the back of an ebonite panel which is capable of being removed from its containing case so that the wiring can be performed on the work bench, and with these conditions every terminal is readily accessible and the wiring is robbed of much of its terrors. On the other hand, if the set is so placed that some of the components are on an ebonite panel and others are located within the case, with perhaps the tuning coils mounted on the top or side of it, the wiring difficulties are necessarily enhanced.

All these points should therefore be borne in mind when designing or building a set. For the actual wiring, very few tools are really necessary. Fig. 1 illustrates a choice of these. They include two pairs of flat-nosed pliers, one at least of which should be of the side-cutting variety; a self-heating or other small soldering iron; some solder and fluxite or other soldering flux. A quantity of square tinned copper bus bar, flexible wire and tinned copper wire about No. 18 gauge are generally also necessary, and some systoflex or insulated sleeving for covering exposed parts of wires which might possibly be liable to short-circuit.

The initial preparation for wiring comprises the construction of a simple former for making the angle pieces, such as that



TOOLS USED IN WIRING

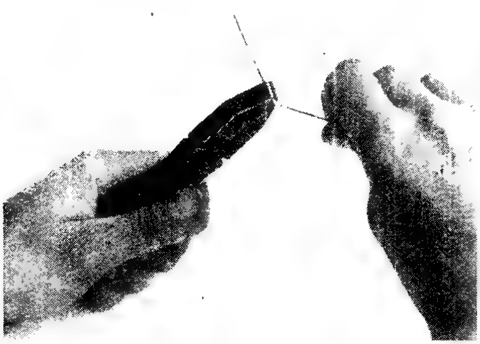
Fig. 1. Here are included two pairs of flat-nosed pliers, soldering iron and flux, square tinned copper bus bar, flexible wire, tinned copper wire and insulating sleeving

ANGLE FORMER IN USE

Fig. 2. For making neat square bends the angle former will save the constructor's time and make a very neat job

illustrated in Fig. 2. This is merely a flat wooden base to which a rectangular block of hardwood is screwed. All four corners should be right angles, and it is used to bend the wires at right angles by forcing the wires into close contact with the guide block.

The most important preparation is that illustrated in Fig. 3, which consists of grasping a suitable length of wire between two pairs of pliers held in the right and left hand, when the wire is stretched or pulled out to straighten it. The right-angle bends are primarily called for in most wiring arrangements, and if any number are required to be made, the bending block should undoubtedly be made up, but for only one or two bends the method illustrated in Fig. 4 should be suitable. The bend is made in this case by grasping the wire with a pair of flat-nosed pliers at the point where the bend is to be made. The other part of the wire is then pulled with the right hand while the pliers are twisted with the left, thus pulling and bending the wire to the required angle.



MAKING AN ANGLE BEND

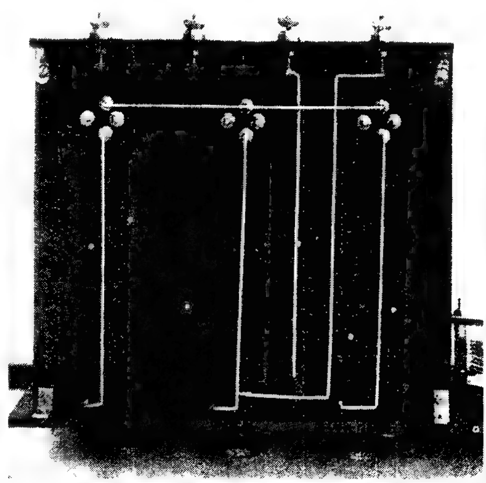
Fig. 4. In this operation the wire is bent with the aid of a pair of flat-nosed pliers, as shown here. Note how the wire is held

Practically speaking, there are two systems by which a set may be wired. All the connexions can be made with ordinary insulated copper wire about No. 18 gauge. Ordinary good quality bell wire gives quite satisfactory results. If this material is used, the wires can be worked in any direction and their ends connected at the requisite points. The result, however, is very unworkmanlike.

STRAIGHTENING WIRE

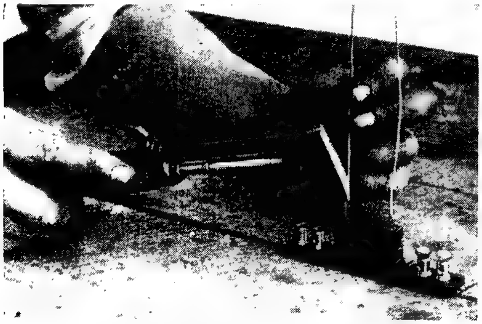
Fig. 3. This simple operation is at the same time one of the most important in the preparation for wiring

Most modern wiring is carried out by the system often known as the anti-capacity system. In its essentials each separate wire is so positioned on the set that it does not touch or come in close proximity to any other wire or metallic connexion. On the score of neatness and efficiency all the bends in the runs of the wires, when connected by this system, should be at right angles. The wires



WIRING A VALVE PANEL

Fig. 5. This illustration presents an example of neat wiring beneath a valve panel. The filament circuit only is wired



SOLDERING CONNEXIONS

Fig. 6. By soldering wires to the small components the resulting connexions on the panel are greatly simplified

themselves should run from point to point in straight paths. Ordinary tinned copper wire about No. 18 gauge can be used for this work, but it is preferable to use a smaller gauge of square-sectioned tinned copper wire. Not only is the sectional area of this wire greater, gauge for gauge, than the circular wire, but it is much stiffer, and therefore retains its position without much risk of its being accidentally moved, as should this happen the wires may be liable to short circuit.

By the anti-capacity system of wiring the air is relied upon as the insulator, and it can usually be assumed that if a minimum gap of $\frac{1}{4}$ in. be left between the conductors carrying the low-tension voltage and a clearance of $\frac{1}{2}$ in. between the conductors carrying the high-tension voltage, ample insulation is provided. Those wires which carry the high-frequency current should as far as possible be kept remote from one another, and should cross each other at right angles. So far as the positioning in the set will allow, the wires carrying the high-frequency current should not run in parallel lines, as it is sometimes considered that such an arrangement tends to increase the self-capacity of the set as a whole.

Perhaps one of the most important features in good wiring is the neatness with which the wires are arranged on the set and the care with which the connexions are made. In Fig. 5 an example showing the low-tension connexions beneath the valve panel of a three-valve set are clearly shown, from which it will be seen that square tinned copper wire is employed, the connexions being carried out by soldering.

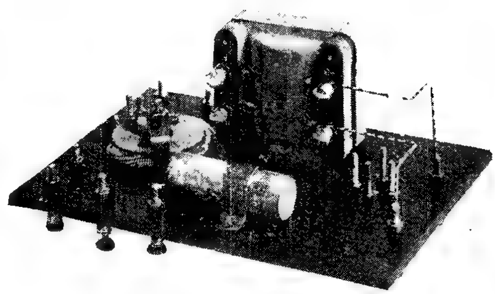
For good results it is imperative to make metallically and electrically good connexions. This can only be accomplished by well-made soldered joints, in which the conductor and terminal, or other connecting points, are metallically connected by solder. In a poorly made joint considerable loss in efficiency will result from the presence of a film of flux or oxide between the two joint faces, although the exterior will appear sound by virtue of the presence of the film of solder.

If the amateur is in doubt as to his ability to make good soldered joints the joints can be made by means of nutted connexions, that is, an eye should be turned on the end of the wire and slipped over the screwed shank of the terminal or other connecting point and good contact effected by screwing a lock nut down firmly on to the connecting wire, particular care being taken to clean off any suggestion of grease or dirt and to make the connexions with mechanically clean nuts, wires and screws.

It will often be found to be desirable to solder connexions or connecting wires to various small components, such, for example, as the condenser illustrated in Fig. 6. The components of this type are generally provided with soldering lugs, usually having a small hole through them. The most effective method of making a connexion is to turn over the end of the wire to a right angle, slip it through the hole, and solder it firmly to the lug.

For this sort of work a small self-heating soldering iron is very useful, as it can be maintained at a uniform and correct working temperature, and is instantly ready for use.

In undertaking the wiring of a set it is highly desirable to adopt some regular plan and to divide the work into a series of sections, commencing, for example, by



TRANSFORMER CONNEXIONS

Fig. 7. The input terminals are here shown connected to the primary windings of the transformer behind the panel

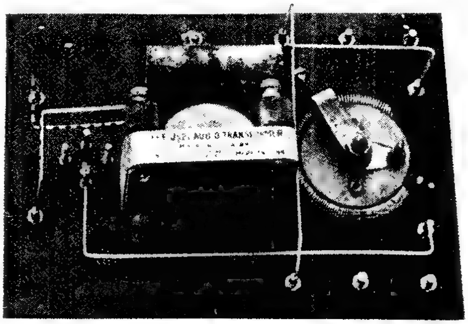


Fig. 8. Here the connexions to the telephone terminals are shown completed and in place

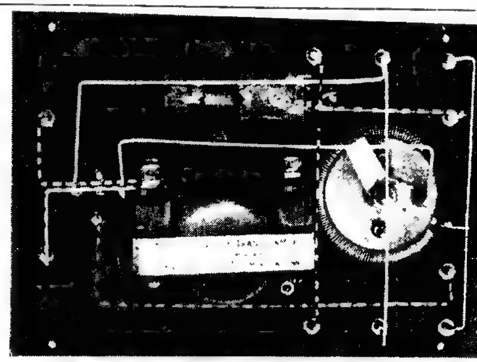


Fig. 9. In this view the filament connexions are indicated in bright wires, connexions previously made being shown dotted

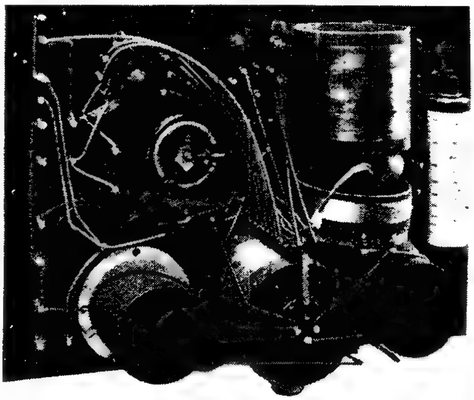


Fig. 10. Another panel is shown here with wiring carried out, using insulated sleeving

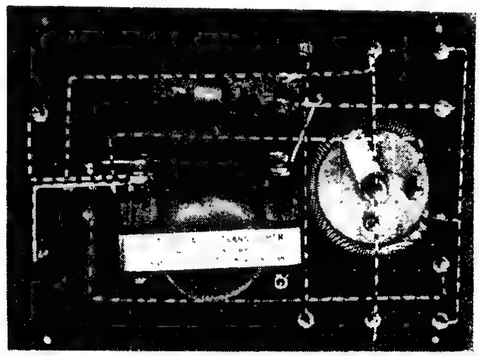


Fig. 11. This illustration shows the panel in Fig. 9 with the amplifier circuit almost complete

DIFFERENT STAGES IN WIRING A RECEIVER PANEL

wiring up the aerial circuit. Another section may include the whole of the low-tension connexions to the filaments of the valves and the other points in that circuit, and as each connexion is made it should be marked off on the circuit diagram, thus reducing the chances of error.

An example of wiring in this manner is illustrated in Fig. 7, which shows a standard low-frequency single-valve amplifier with grid-biasing battery, the whole of the components being mounted beneath an ebonite panel. The first step in this case is to connect the two "input" terminals with the primary winding of the transformer, these two wires being soldered respectively to the input terminals at one end, formed into eyes, and attached by means of terminal nuts to the primary side of the transformer at the other ends.

The next step will be to connect the plate or anode terminal of the valve holder to the telephone terminals, this wire being shown with others in Fig. 8. As this particular set was to be used as a unit with others, three connecting terminals are fixed on opposite sides of the panel, and consequently they have to be connected by a bridging wire on the underside. One of these wires is seen in Fig. 8 connecting the upper pair of terminals, and a branch is taken from it to the second telephone terminal. This bridging wire connects to the high-tension positive side.

The branch from the bridging wire is a straight piece of wire, bent over near one end to a right angle, with one end soldered to the shank of the telephone terminal and the other overlapped and soldered to the bridging wire. A further stage in the progress of the wiring is illustrated in Fig. 9, which shows two other bridging wires similarly fitted to the foregoing example, with branch connexions to various points on the set. The wires that have previously been fixed are in this case shown by dot and dash lines, so as to isolate the other wires and render them clearer, a method which will be found of considerable advantage to the novice.

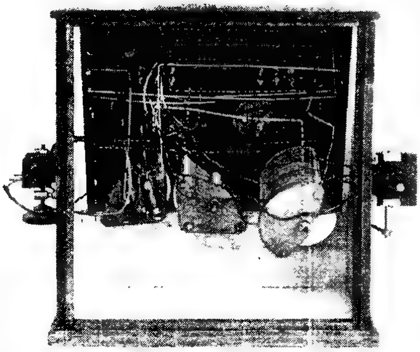


Fig. 12. In this set the various circuits in use are indicated by differently coloured wires

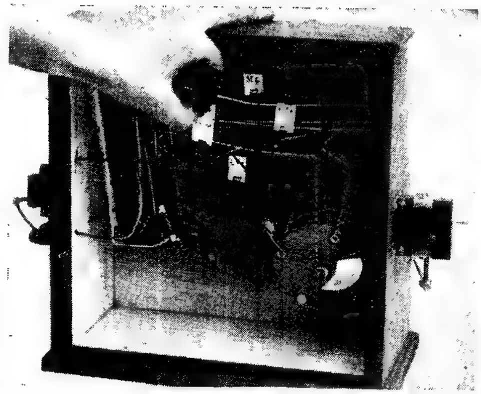
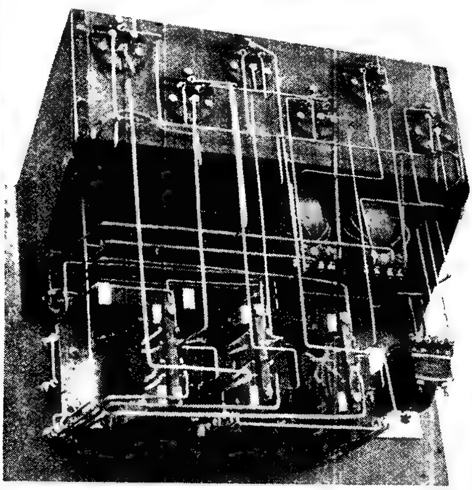


Fig. 13. How ordinary gummed paper tags may be employed to mark the different wires



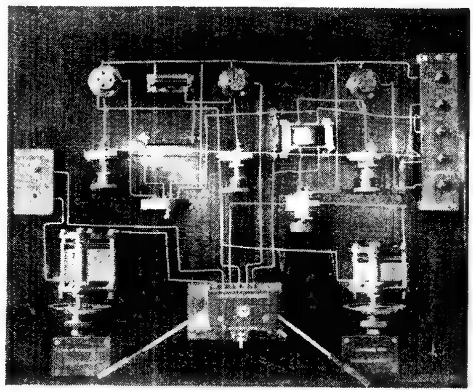


Fig. 14 (left). Very heavy wire is used in this neatly made set. Fig. 15 (above). This arrangement makes for easy tracing of wires

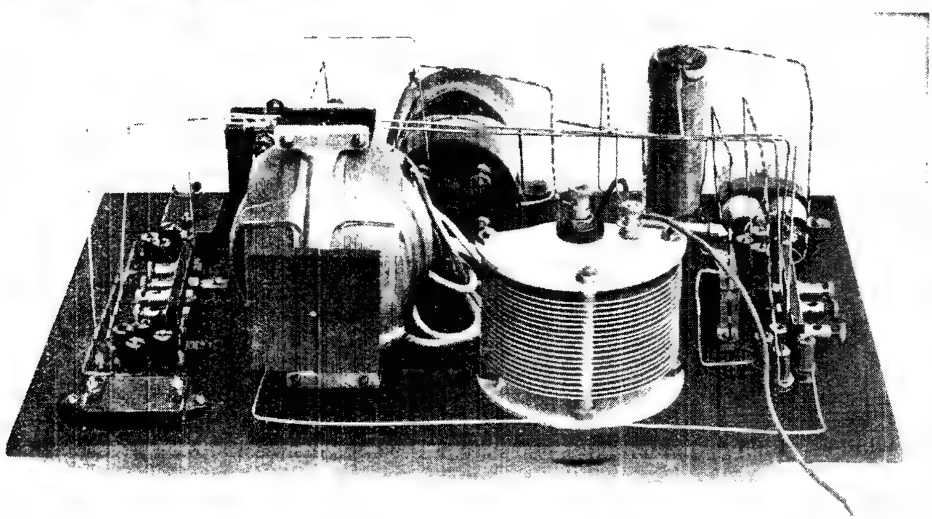
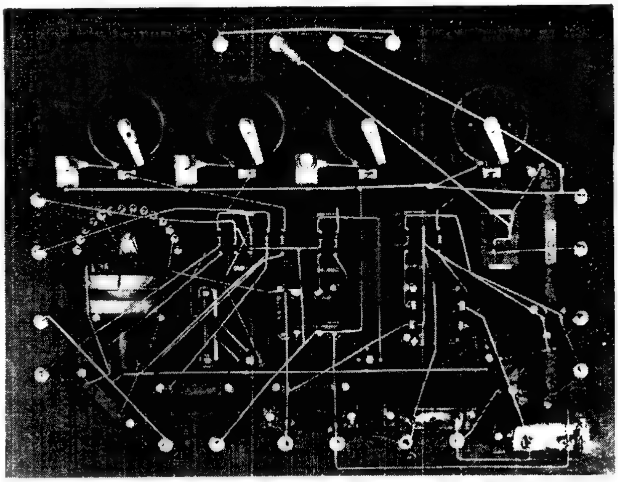


Fig. 16. When this set was wired connexions were made in flexible wire, sleeving and bare wire, as is clearly shown

VARIOUS WIRING ARRANGEMENTS IN LARGE-SIZE SETS



WIRING OF BURNDEPT ULTRA IV SET

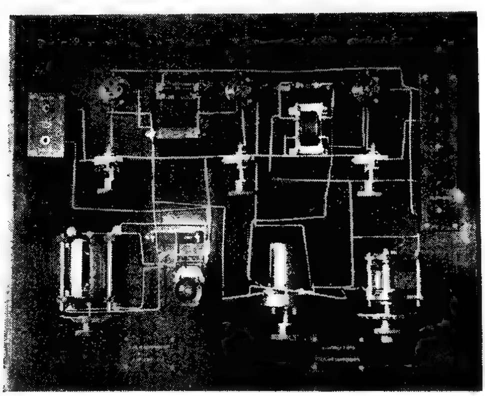
Fig. 17. Each connexion here is made in as direct a line as possible. The L.T. circuit is carried out in heavy-sectioned wire to minimise resistance

Courtesy Burndept, Ltd.

The wiring to the grid-biasing battery, which is shown in Fig. 11, is carried out by soldering one wire to the outer zinc case and connecting this by means of a soldered contact, or other convenient means, by another wire to one side of the secondary of the transformer. Connexion from the centre or carbon element of the battery is made by soldering a wire to it and connecting the other end to the low-tension negative wire.

By adopting the dot and dash system to indicate the various parts of the circuit, considerable saving of time results. A development of the same idea, as illustrated in Fig. 12, is to paint the various circuits in different colours, or to adopt different methods of dots and dashes. For example, the high-tension positive wires could all be painted bright red, the common negative wire green, and so on. This has the advantage that if the work is left until a later day to be completed and a note is made of the colours, it is much easier to carry on at the point where the work was discontinued.

A further device, which is pictured in Fig. 13, is to use small white cardboard tags, which can be clipped on to the principal wires, these tags being marked appropriately, as, for instance, H.T positive, L.T. negative, and so on. An example showing the use of anti-capacity wiring, and also flexible wires and those which are covered with sleeving, is given in Fig. 16.



STERLING THREE-VALVE SET

Fig. 18. This set has a tuned-anode H.F. coupled valve followed by one stage of L.F. and a rectifier. The components are well spaced for wiring

In another example, illustrated in Fig. 10, the wiring is carried out in insulated sleeving. A point that should be noted is the neat manner in which the leads from the inductance tappings are taken to the stud switch at the top.

The rear of a marine type six-valve amplifier by the Radio Communication Co., Ltd., is shown in Fig. 14. A feature of this instrument is its compactness and the parallel arrangement of the leads. Very heavy wire is used throughout, for where wireless sets are put to marine usage they are subjected to very rough handling, and must accordingly be made very robust.

Bare wiring is used on the Burndept Ultra IV set, as shown in Fig. 17. In this instance each connexion is made from point to point in as direct a line as possible. The low-tension circuit is carried out in wire of very heavy section in order to minimise resistance. Every wire is bent on its own special former during manufacture. This process ensures each set being identical in internal capacity as far as the wiring is concerned, and also facilitates assembly.

An excellent way of connecting up components for experimental purposes is shown in Figs. 15 and 18. This consists of arranging the separate items on a base-

board well spaced out, and in convenient positions for handling, the actual wiring being done with stiff, bare, tinned copper wire. The set in Fig. 18 is a tuned-anode high-frequency coupled valve followed by rectifier and one stage of low frequency. Variometer aerial tuning is fitted and a special form of Sterling anode resistance unit. Fig. 15 shows a similar arrangement, except that a three-coil holder tuner is fitted with reaction on the secondary, while the high-frequency coupling is effected with a transformer having a tuning disk.

Arranged in this way the whole of the wiring is distinctly visible, and enables the circuit to be studied at will, and any alterations or additions made with the minimum of trouble. One small but important point is the use of the insulated panel for the battery and telephone connexions.

WOLLASTON WIRE. Name given to an exceedingly fine platinum wire coated with silver. An ordinary platinum wire is heavily coated with silver, and is then drawn out as fine as possible. The central core of platinum, by this means, can be made only a few ten-thousandths of an inch thick. Such fine wire is used in electrolytic detectors (*q.v.*).

WOOD'S METAL. Soft metallic alloy with a low melting-point. It consists of two parts of lead, one part of tin, four parts of bismuth, and one part of cadmium by weight. The alloy has the great advantage of melting at a low temperature, about 60° C., and is extremely useful for the fixing of crystal detectors in their cups and so ensuring a firm metallic contact. On page 561 appears a photograph showing this use of the metal, which is usually sold in the form of a rod.

WORK. Term used in physics. When a body is displaced by a force acting on it work is said to be done on the body, and the measure of that work is the product of the force and the distance the body is moved in the direction of the force. Power is the rate of doing work. The foot-pound-second unit of work is the work done by one poundal in moving its point of application one foot, and is called a foot-poundal. The C.G.S. unit of work is the work done by one dyne in moving its point of application one centimetre, and is known as the erg. One foot-poundal equals 421,390 ergs.

The erg is too small a unit for practical purposes, and in electrical engineering three additional work or energy units are employed, namely, the joule, equal to ten million ergs; the watt-hour, equal to 3,600 joules, and the kilowatt-hour, the Board of Trade unit. *See* Erg; Joule; Power; Units; Watt; etc.

X

X-RAYS. Invisible rays derived from an electrical discharge in a highly evacuated tube which possess the property of being able to penetrate through many bodies which are opaque to light. X-rays are not used in wireless, but it was due to researches on these and other forms of discharge that the electronic theory of electricity was propounded, and the initial experiments in the propagation of electric waves through space started.

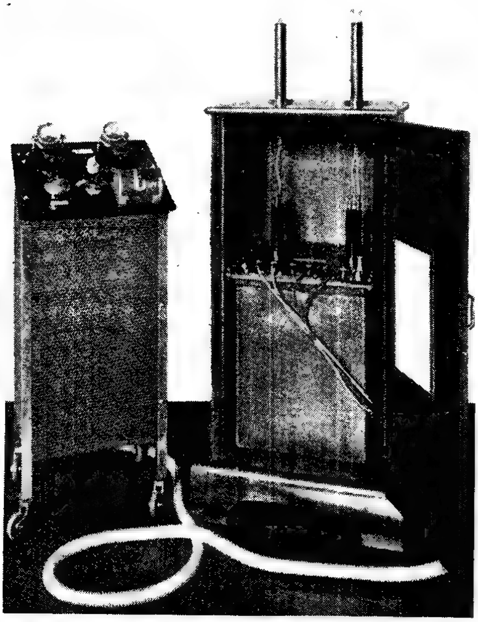
The apparatus for the generation of X-rays consists essentially of some form of high-voltage transformer, such as an induction coil (*q.v.*) and a Crookes' (*q.v.*) or Coolidge vacuum tube. An illustration of the latter form of tube appears in Fig. 1, from which it is clear that it is an elongated tube with a spherical portion near the centre. The electrodes are carried in the tubular portions and terminate opposite one another within the sphere. The ends of the electrodes are spaced some distance apart, one being inclined at an angle of 45 degrees. It is from this latter electrode that the rays are projected from the tube.

In Fig. 2 is shown typical high-tension apparatus for X-ray working. On the right, within the cabinet, is an oil-immersed transformer capable of giving a peak

COOLIDGE VACUUM TUBE

Fig. 1. This type is one of the many vacuum tubes used in the generation of X-rays

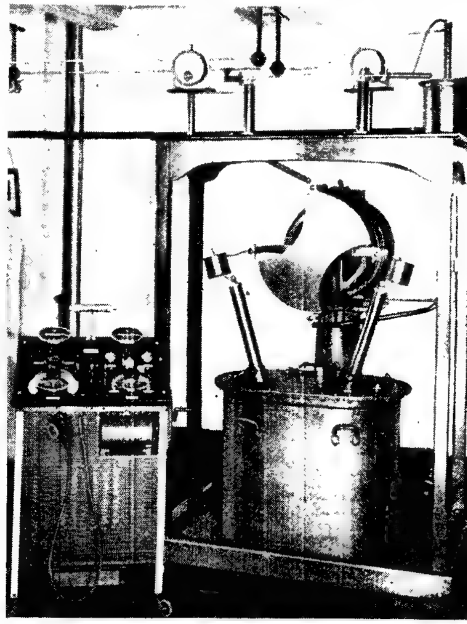
Courtesy British Thomson-Houston Co., Ltd.



H.T. X-RAY APPARATUS

Fig. 2. On the right here is the oil-immersed transformer capable of giving a voltage of 90,000

Courtesy Watson & Sons, Ltd.



LARGE X-RAY OUTFIT

Fig. 3. With this X-ray apparatus a voltage of 150,000 may be obtained.

Courtesy Watson & Sons, Ltd.

voltage of 90,000. The panel on top of the left-hand stand is fitted with the necessary switch-gear and meters, the body within the expanded metal shields containing resistances, etc.

Fig. 3 shows a much larger X-ray outfit, capable of yielding a voltage of 150,000. A high-tension commutator type of rectifier is fitted. This apparatus may be used in conjunction with a vacuum or gas-filled type of tube, whichever is desired.

X'S. Erratic noises heard in the telephones which are not due to any inherent fault in the receiving set. They are usually produced by natural ether waves, as those due to a thunderstorm. X's are also called statics or atmospherics or strays. *See* Atmospherics.

XTRAUDION VALVE. Name given to a valve manufactured by the Economic Electric Co. The valve differs in construction from the standard valve in that the anode is a metal plate bent to form a channel section instead of the usual cylinder. The grid is of robust construction, and completely surrounds the straight filament wire.

The filament of the Xtraudion requires a voltage of 4, and at this maximum consumes ·4 ampere. The valve is a hard one, the vacuum being of a very high order. The anode voltage is 50. The valve will operate effectively in any circuit in which the standard R has been used, but for use as a rectifier a 5 megohm grid leak is required. A dull emitter form of this valve is the Dextraudion, which takes only ·1 ampere at 1 volt and from 20 to 60 volts on the anode. It has a tough filament of special character and will operate on a current so low as ·025 ampere at ·3 to ·5 volt, and thus makes a close approach to a "cold emitter." At these low values the filament cannot be seen to be alight. When supplied with the correct value of current the filament glows a dull red only. The saturation point is high, so that it will work a loud speaker effectively with 2 or 3 volts grid bias. *See* Valves.

XYLONITE. Trade name for a particular form of celluloid (*q.v.*).

Y

YAGI SPARK GAP. Form of spark gap due to H. Yagi. This is a quenched spark gap, the electrodes of which are aluminium and brass. The gap functions in an atmosphere of coal gas. The properties and general functioning of the gap are similar to the Chaffee spark gap (*q.v.*).

Y GROUPING. System of connecting up three-phase windings. The circuits start from a common junction and their three ends go to the three lines. *See* Delta Connexions; Mesh Grouping.

YOKOJAMA, EITARO. Japanese wireless expert. Born in 1883, he was educated at the Engineering College of the Tokyo Imperial University, making a special study of wireless. He was appointed to the Electro-technical Laboratory of the Japanese Ministry of Communications to carry out research work in wireless telegraphy and telephony. He was one of the inventors of the T.Y.K. oscillation gaps for radio-telephony, for which he received many distinctions. In 1910 he was appointed head of the Radio Section of the Electro-technical Laboratory. Yokojama, who is one of the most brilliant Japanese wireless experts, is a member of the Institute of Radio Engineers, America, and other scientific societies.

Z

ZENNECK, J. German wireless expert. Born April 15th, 1871, at Wurtemberg, he was educated at Tübingen. In 1895 he was appointed assistant in the Physical Institute in Strassburg, a post he held until 1899, when he carried out a series of tests in wireless telegraphy in the North Sea. In 1905 he was appointed assistant professor of physics at the Institute of Technology, Brunswick, 1906, and afterwards professor at Dantzic, 1911, and Munich, 1913.

Zenneck is one of the most brilliant of the German wireless experts. He has written a number of authoritative books on wireless and a very large number of articles on electro-magnetic oscillations.

ZINC. Metallic chemical element. The chemical symbol is Zn; melting point, 786° F. The specific gravity of cast zinc varies from 6·8 to 6·9, that of rolled zinc from 7·15 to 17·9. The heat conductivity is 36, compared with silver at 100; electrical conductivity 29·6, compared with silver at 100. The ultimate tensile strength is 5,000 lb. per square inch for cast zinc.

In colour zinc is bluish-grey, it is practically non-corrosive in the atmosphere, is capable of taking a high polish, is unaffected by water, but is soluble in nitric acid and in soda and potash solutions. Pure zinc is attacked very slowly by sulphuric acid, but this feature is one of the greatest applications of zinc in wireless work and in electrical work generally.

Zinc is one of the most important components of most dry batteries. It forms the negative terminal in most small dry batteries, such as those composing the high-tension battery, and in those used for dull emitter valves. Zinc in rod form is used in most forms of wet cells, especially the Leclanché types (*q.v.*).

Another application of zinc is in the galvanizing process, in which iron or steel is immersed in molten zinc, which then forms a protective coating, preserving the ferrous metal from the effects of damp. An example is the galvanized wire ropes used in aerial mast construction. Zinc when overheated gives off poisonous fumes which should never be inhaled. The fumes are sometimes met when heating brass or other alloys containing zinc. Zinc is best soldered by the use of a flux composed of spirits of salts, which should be wiped from the surface of the zinc immediately the joint has been completed, or corrosion will follow.

ZINCITE. Native oxide of zinc. Zincite crystals are distinguished by their red colour, often broken up by orange-yellow streaks. The crystal is one of the best-known rectifiers in combination with certain other crystals. The combination zincite-chalcopyrites is the well-known perikon detector. Zincite may also be used with contacts of copper, bornite, galena, iron pyrites, silicon and tellurium.

With chalcopyrites the contact of the two crystals should be on the light side. With iron pyrites the pressure is not important, the unilateral conductivity remaining fairly constant for most pressures. The worst combination is zincite-galena, which has a poor unilateral conductivity. *See* Crystals.

ZIRCONIUM. One of the metallic elements. Its chemical symbol is Zr, and atomic weight 90·6. Zirconium is an iron-grey powder in one form, or it may be made to crystallize. The crystals look like antimony, are very brittle and extremely hard, being capable of scratching glass and rubies. Zirconium resembles thorium in many of its chemical properties, and for the control of the vacuum in high vacuum valves a small quantity of thorium or zirconium is included in the tube. These metals combine with hydrogen, oxygen, nitrogen, etc., to form compounds of very low vapour pressure.

CLASSIFIED INDEX

This index is supplementary to the main alphabetical headings of the WIRELESS ENCYCLOPEDIA, *and is designed to bring together references which, though having some relations in common, are necessarily scattered through the body of the work.*

Thus amplifiers, condensers, valves and similar components are described under their specific names in the Encyclopedia in addition to the general articles on Amplifier, Condenser, Valves, etc. In this classified index they are all brought together under their general headings for the convenience of readers who are not familiar with the specific names. Similarly, such general headings in this index as Circuits, Coupling, Insulating Materials, etc., will be found of great assistance in the study of the various branches of wireless practice.

It is to be noted that the alphabetical headings of the WIRELESS ENCYCLOPEDIA *itself are not, as a rule, repeated in this index, and when reference is required to a specific article the text matter of the work, and not this index, should be consulted.*

A

W

Introductory Articles

Special Articles by Leading Authorities

Special Articles by Leading Authorities (continued).

Plates in Photogravure and Colour

END OF THIRD VOLUME

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